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AUTHOR: Lance C. Labun

COMPANY NAME: Safe, Inc.

COMPANY ADDRESS
5032 S ASH AVENUE, STE 101
TEMPE, AZ 85282-6842

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5032 S Ash Avenue, STE 101
Tempe, AZ 85282-6842

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14. ABSTRACT

The method and results of a study using rotary wing crash data from the Army Aviation Mishap database are reported. The study was conducted to support the Full Spectrum Crashworthiness initiative with the objective of providing a current basis for revising the crashworthiness design criteria. For this study, crashes were divided into two types: directly to terrain, and those following an inflight obstacle strike. Thirty percent of the crashes studied were post-obstacle crashes and this fraction appears to be higher for the newer generation aircraft. The two crash types differ in both kinematics and outcomes. The post-obstacle crashes were characterized by higher vertical velocities, more vertical impact angles, and a broader distribution of attitude angles. The post-obstacle crashes analyzed were less survivable and more injurious. Data on the impact surface revealed that 16 percent of all crashes occurred onto prepared surfaces, whereas 66 percent occurred onto sod. Crashworthiness was evaluated by estimating the velocity above which all aircraft occupants experienced severe injury. A recommendation is made to reconsider crashworthiness strategies that are functional only for aircraft impacting vertically and close to the normal flight attitude.

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SUBMITTED TO	**Katherine M. Kearney**	**John Crocco**
	Contract Specialist Aviation Applied Technology Directorate / RDMR-AAC Lee Blvd., Bldg. 401 Fort Eustis, VA 23604-5577 katt.kearney@us.army.mil	COR (T) Aviation Applied Technology Directorate / RDMR-AAF Lee Blvd., Bldg. 401 Fort Eustis, VA 23604-5577 John.Crocco@us.army.mil

Prepared By :	**Approved By :**
Dr. Lance Labun *Principal Investigator*	Stanley P. Desjardins *President*

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Revision Date	Section / Title	Description of Revision(s)
July 2014	Appendix H: Injury Distribution Tables (H1 – Fraction of All Injuries in Each Body Region; H2 – Fraction of Occupants Injured in Each Body Region)	Changed the data presentation from map format to tabular format, removed body maps, corrected values reported for each body region (for more details, refer to Appendix H, pp. H1-2 and H2-2).

AATD Helicopter Mishap Analysis

Final Technical Report

1.0 – INTRODUCTION (PURPOSE AND SCOPE)

This crash mishap analysis effort is a part of the Full-Spectrum Crashworthiness (FSC) effort. The objective of FSC is to develop and document new crashworthiness design criteria for military rotorcraft. This effort was to research and quantify the dynamics of military aircraft crashes to be used as the quantitative basis for these design criteria.

The work conducted by Safe, Inc. analyzed historical data on rotorcraft crashes (mishaps) and identified trends based on contributing factors to the survivability of a crash, such as, but not limited to: rotorcraft configuration, design, environment, impact surface, sink speed, disk loading, and mission weight/gross weight. The study investigated the velocity and impact angles by aircraft type.

After identifying mishaps that were actually crashes, and extracting the desired data for only these crashes, the extracted data were analyzed. Various plots and tables were created to illuminate trends in the data and to provide understanding of cause and effect. Regression analysis was used to determine which trends are indeed statistically significant and which conclusions can be quantified. Regression analysis was also used to create quantitative models for determining the injury outcome of models.

2.0 – SUMMARY OF EFFORT CONDUCTED

This investigation gathered and analyzed detailed information describing aircraft crashes and their outcomes for the purpose of revising the crashworthiness design criteria applied to U.S. Army aircraft. The study covered nine aircraft types. Two generations of attack helicopters were studied: AH-1 and AH-64. Two generations of utility helicopters were studied: UH-1 and UH-60. Three observation helicopters were studied: OH-6, OH-58A/C and OH-58D. The OH-58D was studied as a separate aircraft from the OH-58A/C because the D-model is substantially redesigned compared to the A and C models. In particular, the main rotor design is fundamentally different. The CH-47 is a twin main rotor helicopter and the largest helicopter in the study. The C-23 was initially included in the study with the expectation that this light, fixed wing aircraft could serve as a surrogate for the V-22 aircraft in airplane mode. However, there were only three C-23 crashes and all three proved to be non-survivable and hence no information on crashworthiness could be extracted.

2.1 – METHODOLOGY

The detailed data on the crashes came from the U.S. Army Aviation Safety Database at the Combat Readiness Center. The information from the database included parameters describing the aircraft and its flight prior to the emergency, parameters describing the kinematics of the crash, and parameters describing the outcome of the crash in terms of damage to the aircraft and the injuries to the occupants. One narrative was provided for each crash that described to the extent available the sequence events leading up to the crash, described the crash, and the outcome.

The primary interest of this investigation is to improve the crashworthiness of aircraft; therefore, the first step was to select the crashes out of all the mishaps recorded in the database. This selection process was accomplished by reviewing all of the narratives and checking the description in the narrative against the impact velocity data. A new parameter was inserted into the database files, which identified whether the mishap was a crash (YES) or not a crash (NO) (Section 3.1.2). A mishap was defined to be a crash, if the aircraft obviously impacted the terrain or an object AND there was measurable damage to the aircraft. In

cases where the damage was so minor that the crew continued to fly the aircraft, the event was NOT a crash. The database differentiates between inflight impacts and terrain impacts. Inflight impacts are those where the aircraft impacts an obstacle above the terrain level and then subsequently lands or crashes into the terrain (for brevity these crashes are referred to as either IT&TA crashes or post-obstacle crashes). The author anticipated that crashes following an inflight impact would have different kinematic characteristics than the crashes that occurred directly into terrain (crashes directly into the terrain are referred to either as T crashes or direct to terrain crashes). Consequently, the two types of crashes were identified, and the data maintained in separate groups so that the crash kinematics and injury outcomes could be compared.

Once each mishap in the database files had been identified as to whether or not it was a crash, queries were written to extract the desired data for only the events identified as crashes. The queries were executed to extract the data by aircraft type and by crash type, so each aircraft had two queries in each data category. Each query was written to extract one category of data such as kinematic parameters. For the post-obstacle crashes, two kinematic queries are needed, one to extract the kinematic information for the terrain impact and one to extract the kinematic information for the inflight impact. A pair of queries for each aircraft type extracted data about the aircraft in general, the mission, the phase of flight, gross weight, altitude and the number of people on board. Another pair of queries was written to extract data describing the damage to the aircraft in terms of hull crush, and dislocation of major components. Yet another query gathered data on the crash site, including the nature of the surface, a description of the general terrain, and the obstacles in the vicinity of the landing site. A pair of queries gathered data describing post-crash fires and the consequential burn injuries. Data were also gathered on the protective equipment available to the occupants, its use, and its performance. A pair of queries gathered information on the injuries to the occupants, the role of each injured occupant. The data gathered from each query were exported from the database query file format to spreadsheet software. The spreadsheet software facilitated the analysis of the data. Logic statements could be used to select and manipulate values while mathematical calculations could be applied to the quantitative data.

2.2 – Results

The largest difference between this study and previous similar studies is the separation of the crashes into two types on the basis of whether the aircraft had made prior contact with some obstacle. In approximately 30 percent of the crashes studied, the aircraft struck some obstacle above ground level prior to impacting the "ground." These obstacles included other aircraft, wires, buildings, vehicles, and, most frequently, trees. In some cases, striking the obstacle was itself the cause of the crash as in a wire strike; while in other cases the impact was coincidental to an emergency approach to the ground. It was expected at the outset that these outcomes for the "post-obstacle" crashes would be different from the crashes directly into terrain. The direct terrain crashes were entirely survivable (S=1) in 73 percent (Table 2, Section 3.1.4) of the events, whereas the post-obstacle crashes were entirely survivable (S=1) in just 55 percent of the events. The differences in outcomes proved to be easier to reveal and quantify than the differences in crash characteristics, especially the kinematics.

This study includes data for the AH-1, the UH-1, and OH-58A/C aircraft. Due to the large numbers and long lives of these three aircraft, their numbers continue to dominate any parameters calculated for "all aircraft combined." These three aircraft accounted for 419 crashes compared with 207 crashes for the comparable, later generation aircraft: AH-64, UH-60, and OH-58D.

2.2.1 – Kinematics – Velocities

The nature of the crash velocity data is such that it covers a very wide range of values. Consequently, when the means or medians are calculated, very large standard deviations result. Large standard deviations make demonstrating that statistically significant differences exist very difficult. Testing the

velocity data from individual aircraft revealed only a few cases where the difference between the mean or median impact velocity for terrain (T) crashes as was statistically different from the same velocity for the inflight impact followed by terrain impact (IT&TA) crashes (Section 3.1.4).

2.2.2 – Kinematics – Angles

Plots of the flight path and impact angle distributions show a difference between the direct terrain impacts and the post-obstacle impacts. The direct terrain impacts occur markedly more frequently with low flight path and low impact angles than do the post-impact crashes. In contrast, the post-obstacle crashes occur almost twice as often a near vertical flight path and impact angles than do the direct terrain crashes.

The distributions of attitude angles cluster tightly around the nominal aircraft attitude (each angle equals zero). The post-obstacle crashes exhibit a lower peak frequency at zero and a correspondingly broader distribution. In particular, the pitch angle distribution for the post-obstacle crashes is characterized by more nose-down events, which would tend to be more injurious for pilots and to partially neutralize the protection of the landing gear. The roll angle distribution for the post-obstacle has a small second peak in the frequency curve between -80 and -110 degrees (left roll). Crashes at this attitude are effectively lateral crashes to the left side. Once again, no benefit is obtained from the energy absorption strategy, which is effective for predominantly vertical crashes at nominal attitudes.

Analysis for statistical significance found that the difference between the direct terrain crashes and the post-obstacle crashes were statistically significant for the pitch angle distributions of individual aircraft types and of all the aircraft combined. The more frequent nose down attitude in the post-obstacle crashes was confirmed. The statistical analysis failed to find a statistical difference in the roll angle means or medians, but it did confirm that the post-obstacle crashes showed a broader distribution of frequencies. Likewise for the yaw angle.

2.2.3 – Operational Information

These data were perhaps the least revealing area studied. The expectations for analyzing these data were to reveal information about the events leading up to the crash. Unfortunately, this portion of the database is less populated than other areas and the data that is present is not revealing. For example, the phase of operation is reported at three times relative to the crash: as-planned, at emergency, and at termination. The as-planned datum is seldom provided. For all three of these fields combined, the three most commonly reported phases are landing (27 percent), autorotation (12 percent), and cruise (11 percent). The most useful phase information appears to be that labeled as “Phase at Emergency.” This field is the closest information available to identifying the operation mode at the onset of the emergency. At the time of the emergency, cruise (19.4 percent) is the most commonly reported phase, followed by landing (14.3 percent). Combining the three low level flight regimes’ low level, NOE, and contour accounts for 12.1 percent and combining IGE hover with OGE hover accounts for a further 11.4 percent.

In the final segment of the accident sequence, the most common phase reported is the Landing phase (49.6 percent), followed by emergency autorotation (24.9 percent). Training autorotations are cited in 6.5 percent of the crashes. Interestingly, Crash is cited in only 9.7 percent of the events that this study has identified to be crashes. Part of this discrepancy may be attributed to the specific definition given for “Crash” in the instructions. The high percentage of events citing Landing and either type of autorotation indicates that the pilots remained at least partially in control of the aircraft, even though the outcome was measurable damage to the aircraft or injury to at least one occupant. This information suggests that designing helicopters to be crashworthy is justified on the basis that the pilot retains some ability to control the aircraft landing so as to maximize benefit from the crashworthy features of the aircraft.

2.2.4 – Impact Severity

The data on the impact forces were difficult to analyze. In many cases, the values of the standard deviations were larger than the mean values due to a few extraordinarily large values reported. The mean values incorporated both positive and negative values, which tended to bring the mean values closer to zero. The fraction of all crashes with impact directions opposite to the conventional direction was surprising (Section 3.4.1.1).

Cumulative percentile plots (Appendix F) were created using absolute values of the impact severities and these clarified the analysis significantly. The plots revealed a smooth increase in the crash severity up to about 40 G. Beyond this level, large jumps in the severity values appear, indicating that there may be some difficulty in estimating the actual values. Average values were calculated using the absolute values and these means proved quite revealing. Comparing the mean absolute values for the direct terrain crashes to the means for the post-obstacle crashes, the post-obstacles crashes generally had equal or higher values than the direct terrain impacts. This difference is one clear indicator of why the post-obstacle crashes are more injurious than the direct terrain crashes.

2.2.5 – Airframe Damage

The airframe damage is recorded as three or four levels of displacement for 18 regions around the airframe. The damage at each region is also coded for whether that damage contributed to an injury or not. The data are presented in the form of aircraft maps (Appendix G). These maps report the damage frequencies for each region of the aircraft. For each damage level in a region, the frequency that damage in that region led to an injury is reported. The frequency is reported as a percentage of the crashes by that aircraft type. More information could be extracted from these data with further analysis.

2.2.6 – Retention of High Mass Items

For the AH-64, comparing the frequency that high mass items are displaced in direct terrain crashes to the frequency for post-obstacle crashes reveals more frequent displacements for the post-obstacle crashes.

2.2.7 – Impact Surface

An impact surface was reported for approximately 89 percent of all the crashes analyzed. Sixty-six percent of the crashes where the surface was reported occurred onto sod which is a term for a broad range of unprepared, natural surfaces. Just 16 percent of crashes occurred onto prepared surfaces. These relative frequencies remained consistent between both survivable and non-survivable crashes and between crashes directly to terrain and post-obstacle crashes.

2.2.8 – Crash Site Obstacles

Obstacles at the crash site are not necessarily those impacted, but are obstacles in the vicinity of the crash site. Trees were reported as obstacles around 40 percent of the sites for survivable and partially survivable crashes directly into terrain. Trees were reported around 56 percent of sites for non-survivable crashes directly into terrain. Trees were reported as obstacles around 72 percent of the sites for survivable and partially survivable post-obstacle crashes. The corresponding frequency for non-survivable crashes was reported as 60 percent. The next most frequently reported obstacle is “rocks.”

2.2.9 – Injury Data

The data on injuries is recorded in two forms in the database. One form is reported in the AIRCRAFT_INFORMATION† table and consists of the number of people onboard the aircraft injured at various severity levels including those without injuries. These people are identified as either civilian or military. The other form of data is reported in the INJURY_INFORMATION table and consists of detailed information about the injuries to each person and information about the injured person including the person's role aboard the aircraft. The number of personnel covered in these two data sets did not correlate well (Table 52, Section 3.6). The table with detailed injury and role information did not include the uninjured personnel, nor did it appear to include all personnel with the lower severity injuries. Nor did the number of people in major injury categories agree from one table to the other. The data from each table were treated separately and data from each table were presumed to be at least consistently reported between aircraft types within each table.

Injury maps were created similar to those originally presented in the Aircraft Crash Survival Design Guide. These maps display the frequency of injury to various regions of the human body. The frequencies are reported as the fraction of injuries to the body region as a percentage of the number of injuries reported (Appendix H1). An injury map is presented for all personnel combined and one map is presented for each of three personnel roles on the aircraft: pilots, non-pilot crew, and passengers. A second set of injury maps (Appendix H2) was created that reports the frequency of individuals injured in each body region. These maps report the fraction of individuals injured in each body region as a percentage of the number of individuals with reported injuries. These injury maps were not extensively analyzed; however, the injury data were used in other analyses.

2.2.10 – Injuries Due to Post-crash Fire

Sixteen of eighteen fire fatalities are attributed to just two crashes. In both crashes, non-crashworthy, auxiliary fuel systems provided the source of flammable material to sustain the fire.

2.2.11 – Protection Equipment

Four pieces of protective equipment were studied: lap belt, shoulder harness, inertia reel, and seat. In general, pilots, as a group, have all of these items available to them and use them. The situation in the cabin is difficult to generalize. In many cases, the equipment is not available to all personnel; and even when it is available, the equipment frequently is not used (Section 3.8). More functional failures also occur in the cabin. Equipment usage is higher in both models of the OH-58 where the cabin is smaller and more contiguous with the cockpit than usage in the larger aircraft where the cabin and cockpit are less contiguous (Section 3.8).

A difference in performance by protection equipment is recorded between the direct terrain impacts and the post-obstacle impacts. With exceptions for specific devices in the attack helicopters, a higher percentage of "injuries prevented" is reported for direct terrain crashes than for post-obstacle crashes. This trend applies to all four devices and to both the cockpit and the cabin.

Aside from the low usage rates for protective equipment in the cabin, the most remarkable feature of these data is the seat performance. Twenty-one instances of pilot seats "producing injury" were reported, as

† For describing the titles of tables and the titles of data columns, the database format of all capital letters and an underscore for a space is used in this report.

were ten failures to function. In the cabin, seven instances of the seat producing an injury were reported for the UH-1 and ten seat failures were reported between the UH-1 and the UH-60.

2.2.12 – Severe Injury Transition Velocity Analysis

Using a similar analysis to that developed by Shanahan[1] to compare the crashworthiness of two aircraft was modified and applied in this work. The analysis identifies that velocity above which all crashes result in severe injury to all of the occupants. The analysis done previously used fatalities, but this work expands the measurement to include missing, totally disabled, and partially disabled persons. The revised method also simplifies the approach by plotting the fraction of personnel with severe injuries for each crash rather than grouping crashes into velocity increments.

For the vertical speed, the analysis finds that the transition velocity for direct terrain crashes is generally higher than the transition velocity for post-obstacle crashes (Section 3.9.1). The exceptions are the UH-1 and the AH-64. By regrouping the aircraft by rotor technology, it became apparent that the transition velocity associated with the direct to terrain crashes may be associated with the autorotation characteristic and the rotor system configuration, whereas the transition velocity for the post-obstacle crashes is more characteristic of the structural integrity of the airframe.

The application of transition velocity analysis to the ground speed was not productive. Clear transition speeds were difficult to determine or the results were extremely high. These results are attributed to the presence of a few low impact angle crashes for each aircraft type. In these type of accidents, the aircraft slides out over a long distance, reducing the deceleration forces to tolerable levels and allowing partial survivability. The velocities of these crashes are often widely spaced, thus making the determination of a transition velocity less meaningful.

2.2.13 – Regression Analysis

Two forms of regression analysis were performed: linear regression using the fraction of severe injuries as the response variable and ordinal logistic regression using the crash survivability as the response variable. Neither analysis approach achieved predictive models, that is, to say models that can predict crash outcomes given the characteristics from a particular crash. However, the models have confirmed the importance of variables such as the vertical speed and ground speed and have quantified their relative importance (Section 3.10).

While simple to run and easy to understand, the linear regression models disappointed in that the resulting models had low predictive values. One statistic generated by the regression software indicates what percent of the total variability displayed in the response variable is predicted by the regressor (input) variables. These values were generally in the ten to thirty percent range, far short of the percentages that one would hope for the model to explain to be considered truly predictive. These results mean either that important regressor variables are absent from the model or that the there is too much variation in the regressor variables. Many variables that were expected to be important in determining crash outcomes were found not to be statistically significant (Section 3.10). Of the crash parameters, these included the three attitude angles at impact, the crash type, and the disk loading. None of the aircraft design variables were found to be statistically significant either, including the rotor system, number of main rotor blades, landing gear type, or tail rotor position (high or low).

[1] Shanahan, LTC D. F., *Crash Experience of the U.S. Army Black Hawk Helicopter*. In: *Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques*. London, Technical Editing and Reproductions, Ltd. AGARD-Conference Proceedings-532:40-1 to 40-9, September 1992.

The ordinal logistic regression analysis is more complex to run and its results are far from easy to interpret. However, this model consistently found the same parameters significant and predicted similar coefficients for five of the eight aircraft types (Section 3.10.3). Furthermore, the ordinal logistic model consistently included the crash type (terrain or post-obstacle) as significant in determining the survivability of a crash.

3.0 – ANALYSIS OF MISHAP DATA

3.1 – ANALYSIS DEFINITIONS AND PROTOCOLS

3.1.1 – Axes and Angle Conventions

The reference frame conventions used in this report are consistent with those used in the *Aircraft Crash Survival Design Guide* (ACSDG).[2] These axes are depicted in Figure 1. Figure 2 presents the relationship between the terms flight path angle, impact angle, and terrain angle as used in the database and throughout this report.

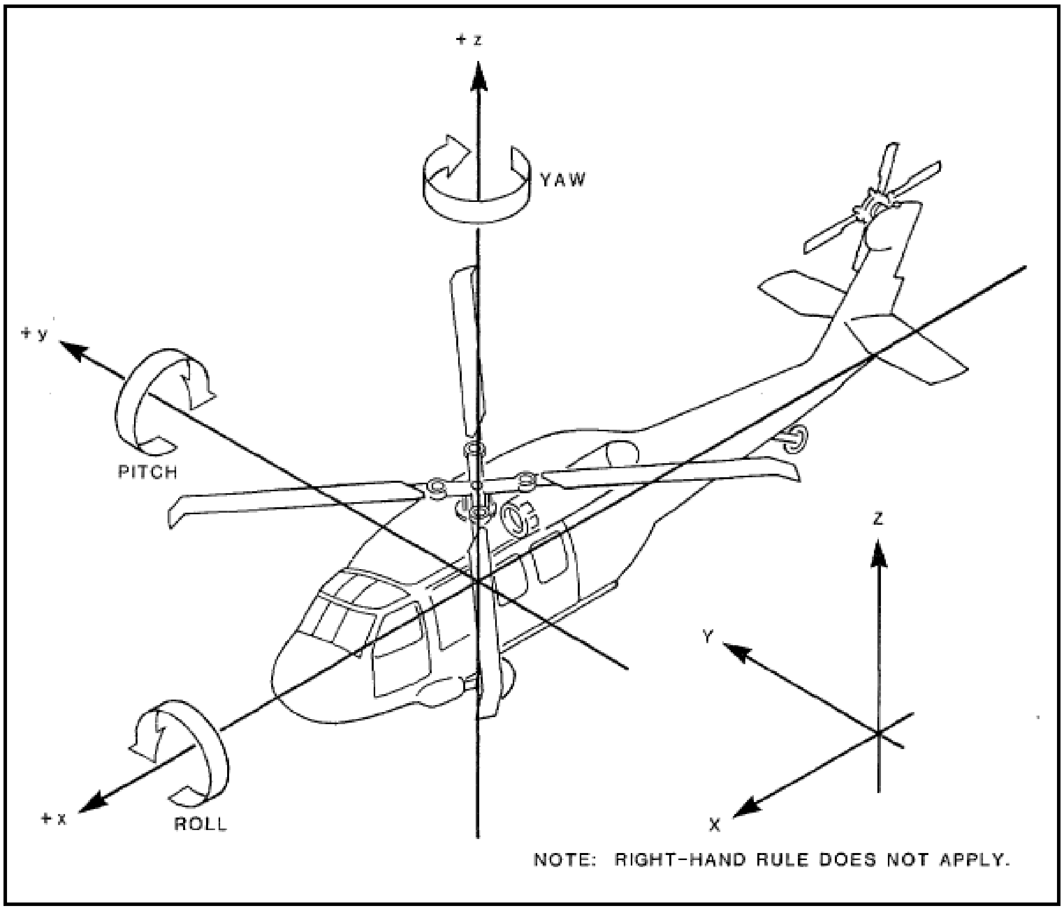

Figure 1 – Helicopter Reference Frame Axes Conventions

[2] Zimmermann, R.E., et al., *Aircraft Crash Survival Design Guide*, prepared for Aviation Applied Technology Directorate, Fort Eustis, VA, USAAVSCOM TR 89-D-22C by Simula, Inc., Phoenix, AZ, 1989.

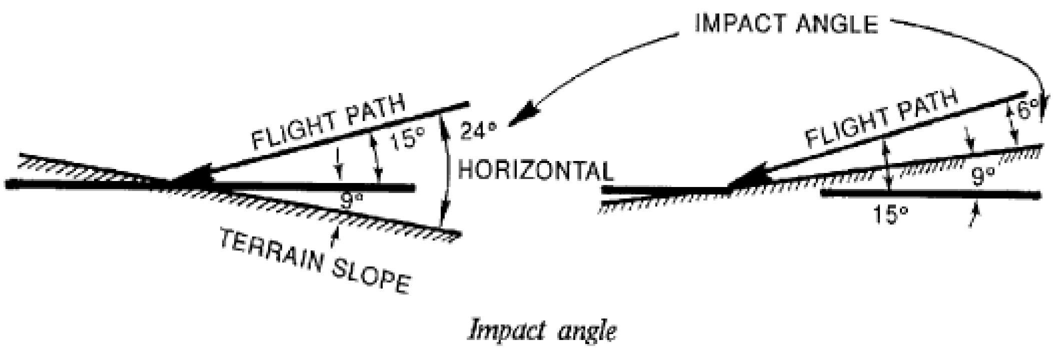

Figure 2 – Relationship between Flight Path, Terrain, and Impact Angles

Five angles are recorded in the accident investigation report: the flight path angle, the slope angle, and the three attitude angles of the aircraft. The flight path angle is combined with the slope angle to calculate the impact angle. Figure 2 presents the relationships between the flight path angle, the slope angle and the impact angle. The flight path is always a positive angle, and the sign convention for the slope angle that a slope rising in the same direction as the aircraft is flying is positive, a dropping slope is negative. Although rare, it is possible to crash down slope. The sign convention for aircraft attitude angles is presented in Figure 1.

The velocities considered in this report consist of two in the Earth Reference Frame (ERF) and three in the Aircraft Reference Frame (AcRF). The two velocities in the ERF are the ground speed and the vertical speed. The other three are the velocities along the three aircraft axes, vertical, longitudinal and lateral.

3.1.2 – Crash Definition

To be useful in this study, a mishap must be considered a "crash." For this study, a crash has been defined as an impact that causes damage to the airframe. For example, minor damage to the main rotor tips or to the tail rotor that is not discovered until after the mission is not considered a "crash." An inflight impact that causes damage to the airframe, but does not result in a subsequent terrain crash, is included as an inflight crash. For example, an aircraft flown through trees, damaging the underbelly or landing gear, but landing safely is included as an inflight crash.

Each mishap is identified by a CASE_NUMBER. The information in the different tables of the database is tied to the particular mishap through this case number. The collision of two aircraft is assigned one CASE_NUMBER. Each aircraft is identified separately with a sequence number and its serial number. Within each aircraft, the occupants were assigned identifying numbers, so that their individual identity can be protected. The case numbers in the original US Army Combat Readiness Center data contain the dates of the crashes. The date can be used to associate the information for a specific crash to specific people. In the data files, the CASE_NUMBER and the aircraft serial number appear in all of the database tables and are used to tie together all the data related to a specific mishap. This effort needs to retain the ability to tie together specific mishap information from different database tables and yet prevent the reader from recognizing the data as being associated with a particular mishap. A scheme was developed for assigning new values for the CASE_NUMBER field to each mishap. These new case numbers do not contain any imbedded information from the old case number or from the mishap. However, the case number is uniquely associated with one mishap. Thus, the data associated with a particular case number all apply to that one mishap.

Each mishap has a summary narrative that is a brief text describing the sequence of events. The initial screening to select the crashes out of all the mishaps was accomplished by reading and analyzing these summary narratives and adding a data column IS_CRASH to the SUMMARY_INFORMATION table. Those mishaps meeting the criteria for being a crash were identified with "YES" in this field. In subsequent database queries, this field was included in the query with a condition that this field be coded as "YES." Table 1 presents the number of aircraft records that were identified as crashes for each aircraft type. The total cases refer to the total number of Class A, B, and C mishaps delivered in the data file.

Table 1 – Number of Mishap Records That Were Identified as Crashes

Aircraft	Total Mishaps	IS_CRASH= "YES"
C-23	129	3
OH-6	178	97
AH-64	398	160
CH-47	578	72
UH-60	669	202
AH-1	806	284
OH-58	1,417	493
UH-1	1,861	565

3.1.3 – Aircraft Types

Nine aircraft types were investigated in this study. Two types of utility helicopters: the UH-1 and the UH-60 are investigated. Both utility helicopters are single main rotor helicopters with conventional tail rotors; however, the UH-60 was designed and built after the advent of crashworthy design practices. Likewise, two attack helicopters, the AH-1 and the AH-64, are investigated. The AH-1 is pre-crashworthy design, and the AH-64 incorporates crashworthiness considerations and hardware. Both are single main rotor helicopters. The CH-47 is the heaviest helicopter in the group and the only twin main rotor aircraft. The C-23 is the only fixed wing aircraft in the group. It is being analyzed, anticipating that data from the C-23 will characterize crashes that may occur with the V-22 operating in airplane mode. The OH-6 is the lightest aircraft in the group; it is a single main rotor observation and scout aircraft designed primarily to carry people. The OH-58 has a similar mission, but is significantly heavier. The OH-58 is unique in that the earlier variants (A and C) used a two-blade, "teetering" rotor system, whereas the newer D model uses a four-blade, "bearingless" rotor system. The two-rotor system designs on the same aircraft provide a unique opportunity to isolate the influence of the rotor system design on crash outcomes. Although, it must be acknowledged that the disk loadings also differ dramatically due to the nearly doubling of the aircraft gross weight in the D compared to the A and C models.

3.1.4 – Crash Types

From mid-1977 to the present, the data recorded in the accident report differentiated impacts with obstacles above ground from impacts with the ground. Thus, in some mishaps, there can be two impacts: an initial impact with the above ground-level obstacle, followed by an impact with the ground. The two different types are referred to as inflight and terrain impacts. Data for the two different types are stored in different data tables within the database. The inflight data include information describing impacts of the

aircraft with obstacles such as other aircraft, wires, trees, and towers. In a few cases, this inflight collision can be with terrain, such as a rotor strike with a rock face that leads to a subsequent crash on to the terrain below.

These two types of crash lead to two types of impacts into terrain. All crashes terminate with an impact into terrain. Some crashes are impacts directly into the terrain, these are labeled as (T) for "terrain." However, there is a second set of crashes where the crash into terrain follows a prior impact with some above-ground obstacle. These crashes are coded (IT&TA) for "Inflight & Terrain After." As will be seen in the discussion on survivability, analyzing these two populations of crashes independently enhances the information to be derived from the analysis. The two crash types are described in greater detail in Section 3.2 – Kinematic Data.

The survivability for each crash is reported by the investigator based on the presence of two factors: humanly tolerable crash forces and livable volume. Each occupant location within the aircraft is evaluated separately. To be considered survivable, the crash forces in all areas must be within the limits of human tolerance and all inhabitable areas of the aircraft must remain "reasonably intact and remain suitable for occupancy. If these criteria are met for at least one, but not all seat/litter positions, then the accident is partially survivable. If no seat positions meet these criteria, then the crash is non-survivable. Fatal injury or occupancy of an inhabitable area is not the criterion for determining survivability.

Table 2 reports the number of crashes in each survivability category for each aircraft type. The data in this block of the investigation form[3] is reported for approximately 95 percent of the crashes. From Table 2, it can be seen that, on average, 73 percent of the crashes studied were survivable and only 14 percent were considered non-survivable. To compare these figures between aircraft types and between crash types, it is expedient to look at frequencies expressed as percents of the total number of crashes for each aircraft type. These values are presented in Table 3.

Table 2 – Crash Survivability Counts for T Crashes by Aircraft Type

Terrain (T)	S=1 Survivable (no.)	S=2 Partially Survivable (no.)	S=3 Non-Survivable (no.)	S=nil No Rating (no.)	Total (no.)
UH-60	17	8	11	2	38
UH-1	74	10	17	3	104
OH-58AC	66	3	11	2	82
OH-58D	26	1	3	3	33
OH-6	28	0	0	1	29
CH-47	14	3	3	1	21
AH-64	28	4	6	4	42
AH-1	52	5	6	3	66
Total	305	34	57	19	415
	73%	8%	14%	5%	100%

[3] DA Pam 385-40, *Army Accident Investigation and Reporting*, Department of the Army, Washington, DC, 1 November 1994.

Table 3 reveals that the fraction of accidents that are survivable vary widely between different aircraft types, from a low of 45 percent survivable for the UH-60 to a high of 97 percent for the OH-6. Looking at the older-generation aircraft, the UH-1 and the AH-1, they generally have higher fractions of survivable accidents compared to the newer-generation aircraft the UH-60 and the AH-64. Comparing the two different configurations of the OH-58 (A/C to D), the fraction of accidents that are survivable are nearly identical, which suggests that the difference between the different rotor system designs cannot by itself explain the difference in survivability in other aircraft types. The dual main rotor CH-47 has a fraction of survivability (67 percent) that falls near the average for the whole group (73 percent).

Table 3 – Crash Survivability Reported as Percent for T Crashes by Aircraft Type

Terrain (T)	S=1 Survivable (percent)	S=2 Partially Survivable (percent)	S=3 Non-Survivable (percent)
UH-60	45%	21%	29%
UH-1	71%	10%	16%
OH-58AC	80%	4%	13%
OH-58D	79%	3%	9%
OH-6	97%	0%	0%
CH-47	67%	14%	14%
AH-64	67%	10%	14%
AH-1	79%	8%	9%

Considering the crashes that occurred following obstacle strikes, Table 4 and Table 5 present data similar to the two tables above. Table 4 gives the number of crashes in each survivability category for each aircraft type. It is apparent from the very small number of events for the OH-6 and the CH-47 that no solid conclusions can be drawn about these two aircraft types. The number of crashes of this type by the UH-60 and the OH-58D are also very limited. Looking at the overall survivability of all aircraft summed together (bottom of Table 4), only 55 percent of the crashes following a collision with an obstacle are completely survivable compared with 73 percent of crashes that occurred directly to the terrain. The balance of the crashes were approximately equally divided between being partially survivable and non-survivable (21 percent each). Both of these frequencies are markedly higher than those for the same categories of the terrain impacts.

Table 4 – Crash Survivability Reported as Counts for IT&TA Crashes by Aircraft Type

Post-obstacle (IT&TA)	S=1 Survivable (no.)	S=2 Partially Survivable (no.)	S=3 Non-Survivable (no.)	S=nil No Rating (no.)	Total (no.)
UH-60	9	5	8	3	25
UH-1	38	9	7	0	54
OH-58AC	22	8	10	1	41
OH-58D	7	3	2	0	12
OH-6	1	0	2	0	3
CH-47	1	1	2	0	4
AH-64	12	7	4	1	24
AH-1	15	7	6	0	28
	105	40	41	5	191
	55%	21%	21%	3%	

Looking at the frequencies for survivability by aircraft type, there is a narrower range of survivability in the post-obstacle crashes than is observed for the direct terrain impacts. The survivable IT&TA (Table 5) crashes range from a low of 25 percent for the CH-47 to a high of 71 percent for the UH-1. The range for the non-survivable frequencies is wider for the post-obstacle crashes than it is for the direct terrain crashes. The non-survivable frequencies range from a low of 12 percent for the UH-1 to a high of 67 percent for the OH-6. This latter value for the OH-6 is remarkable in that, the OH-6 had 97 percent of crashes rated as survivable for the direct terrain impacts. Considering the different design generations, there is no clear difference. The AH-64 has a similar percentage of survivable crashes (50 percent) compared to the earlier AH-1 (54 percent); in contrast, the UH-60 has a lower percentage of survivable crashes (36 percent) compared to the earlier UH-1 with 71 percent survivable.

Table 5 – Crash Survivability Reported as Percent for IT&TA Crashes by Aircraft Type

Post- Obstacle (IT&TA)	S=1 Survivable (percent)	S=2 Partially Survivable (percent)	S=3 Non-Survivable (percent)
UH-60	36%	20%	32%
UH-1	71%	17%	12%
OH-58AC	54%	20%	24%
OH-58D	58%	25%	17%
OH-6	33%	0%	67%
CH-47	25%	25%	50%
AH-64	50%	29%	17%
AH-1	54%	25%	21%

These survivability ratings will be considered as a factor in sorting the analyses that follow in this report. Generally, the Survivable (S=1) and the Partially Survivable (S=2) accidents will be grouped together for analysis separate from the Non-survivable accidents (S=3). When the accidents are grouped this way, the non-rated accidents are treated as Non-survivable [†].

The large difference in survivability between crashes that occur directly into terrain and those that follow obstacle strikes is an important finding. This difference in accident outcome justifies the effort involved in continuing to analyze these two crash types as separate populations throughout the balance of the report.

3.2 – Kinematic Data

The inflight impact data were collected and recorded beginning in 1977. These data begin appearing in the database with mishaps that occurred in the third quarter of Fiscal Year 1977. For consistency's sake, it would be desirable to consider only mishaps that occurred after 1 July 1977 for all aircraft. However, as Table 6 reveals, such a decision would eliminate more than one-third of the AH-1 crashes and more than one-half of the OH-6 crashes. For the OH-6 and the AH-1, all mishaps occurring after 1 July 1977 will be included in the study. To these mishaps will be added those mishaps that occurred prior to July 1977 and can be identified as being direct impacts into the terrain with no prior inflight impact. This inclusion of earlier crashes was also applied to the CH-47 because the sample set was so small. The inclusion of these additional earlier impacts increases the number of accidents included in the study and thus, improves the statistics. Yet, the decision adds only those crashes where the recorded data were mostly likely to be recorded in the same manner as the data were recorded after July 1977. For the C-23, AH-64, UH-60, OH-58, and UH-1, only mishaps occurring after 1 July 1977 were studied.

Table 6 – Numbers of Mishaps before and after July 1977

Aircraft	IS_CRASH before 07-01-77	IS_CRASH after 07-01-77
C-23	0	3
OH-6	53	44
AH-64	0	164
CH-47	9	63
UH-60	0	207
AH-1	100	185
OH-58	109	392
UH-1	189	385

[†] Only 5 percent of the usable T crashes and 3 percent of the usable IT&TA crashes had no survivability rating. For individual aircraft types, the crashes with no survivability rating did not exceed 12 percent (UH-60). Consequently, rather than exclude these crashes, they were assumed to be non-survivable in the absence of reported information. The alternatives would have been to omit them or to presume that the reason for omitting the rating was that the investigator could not decide on the rating. In the latter case, it might be argued that these crashes should have been assigned to the "partially survivable" category.

The kinematics data for the mishaps selected as crashes were extracted as two queries, one that extracted data associated with inflight impacts (Table 7) and one that extracted data associated with terrain impacts (Tables 7 and 8).

Table 7 and Table 8 also contain references to the Department of the Army Form 2397[4], which is the accident investigation form. The instructions for accident investigation reporting are found in Department of the Army Pamphlet 385-40 *Army Accident and Investigation and Reporting*[3].

Each query created a matrix of information with each row being a record associated with one aircraft in a particular mishap. Each column represents a datum field, such as GROUND_SPEED. The data in these queries were then exported to MS Excel. The resulting Excel spreadsheet retained the original data in columns to the left. Columns to the right were created by the analyst and contain formulae and logic statements to manipulate and evaluate the data. For example, the GROUND_SPEED in KIAS (knots indicated airspeed) is converted to feet per second (ft/s). The vertical velocity is converted from ft/min. to ft/s and an algebraic sign is chosen based on the VERTICAL_VELOCITY_DIRECTION datum ("up" or "down"). The velocity angle is calculated by taking the arctangent of the VERTICAL_VELOCITY divided by the GROUND_SPEED. Comparing this calculated angle to the FLIGHT_PATH serves as an internal consistency check on the data. The GROUND_SPEED, VERTICAL_VELOCITY, and FLIGHT_PATH are treated as a group in the accident report. The investigator is asked to indicate which two of the three should be considered the most accurate. If the FLIGHT_PATH and the velocity angle agreed within 15 degrees, these parameters were considered consistent; if they differed by more than 15 degrees, the accuracy indicators were checked and the SUMMARY was reviewed. If reasonable assumptions or inferences could be drawn, then one of the three parameters was adjusted to achieve consistency. In general, the parameter with the “False” accuracy designation was the one that was adjusted. Each change is highlighted on the spreadsheet by coloring the cell and annotating with a comment. The comment describes the change that was made and the basis for making the change. A similar consistency check was applied to the inflight impact data.

[4] DA Form 2397-R July 94, *Technical Report of U.S. Army Aircraft Accident*.

Table 7 – Inflight Impact Kinematics Query

Table	Parameter (Column)	Location on Investigation Form	Comment
All	Case Number	All pages	
SUMMARY_INFORMATION	IS_CRASH	Not in forms	
AIRCRAFT_INFORMATION	MTDS	2397-1/8a	
INFLIGHT_IMPACT_INFO	AIRSPEED	2397-6/1a	KNOTS
INFLIGHT_IMPACT_INFO	VERTICAL_SPEED	2397-6/1b	FT/MIN
INFLIGHT_IMPACT_INFO	VERTICAL_SPEED_DIRECTION	2397-6/1b	U or D
INFLIGHT_IMPACT_INFO	FLIGHT_PATH_DEGREE	2397-6/1c	DEG
INFLIGHT_IMPACT_INFO	FLIGHT_PATH_DIRECTION	2397-6/1c	U or D
INFLIGHT_IMPACT_INFO	PITCH_ANGLE	2397-6/1d	DEG
INFLIGHT_IMPACT_INFO	PITCH_DIRECTION	2397-6/1d	U or D
INFLIGHT_IMPACT_INFO	ROLL_ANGLE	2397-6/1d	DEG
INFLIGHT_IMPACT_INFO	ROLL_DIRECTION	2397-6/1d	U or D
INFLIGHT_IMPACT_INFO	BIRDS	2397-6/1e(1)	Y
INFLIGHT_IMPACT_INFO	BIRDS_HEIGHT	2397-6/1e(1)	FT
INFLIGHT_IMPACT_INFO	AIRCRAFT	2397-6/1e(2)	Y
INFLIGHT_IMPACT_INFO	AIRCRAFT_HEIGHT	2397-6/1e(2)	FT
INFLIGHT_IMPACT_INFO	WIRES_CABLES	2397-6/1e(3)	Y
INFLIGHT_IMPACT_INFO	WIRES_CABLES_HEIGHT	2397-6/1e(3)	FT
INFLIGHT_IMPACT_INFO	VEHICLES	2397-6/1e(4)	Y
INFLIGHT_IMPACT_INFO	VEHICLES_HEIGHT	2397-6/1e(4)	FT
INFLIGHT_IMPACT_INFO	TREE	2397-6/1e(5)	Y
INFLIGHT_IMPACT_INFO	TREE_HEIGHT	2397-6/1e(5)	FT
INFLIGHT_IMPACT_INFO	OTHER_OBSTACLE	2397-6/1e(6)	Y
INFLIGHT_IMPACT_INFO	OTHER_OBSTACLE_HEIGHT	2397-6/1e(6)	FT
INFLIGHT_IMPACT_INFO	PROP_ROTOR	2397-6/1f	Seq. #
INFLIGHT_IMPACT_INFO	PROP_ROTOR_OBSTACLE_DESC	2397-6/1f	Text
INFLIGHT_IMPACT_INFO	ROTOR_MAST	2397-6/1f	Seq. #
INFLIGHT_IMPACT_INFO	ROTOR_MAST_OBSTACLE_DESC	2397-6/1f	Text
INFLIGHT_IMPACT_INFO	TAIL_ROTOR	2397-6/1f	Seq. #

Table	Parameter (Column)	Location on Investigation Form	Comment
INFLIGHT_IMPACT_INFO	TAIL_ROTOR_OBSTACLE_DESC	2397-6/1f	Text
INFLIGHT_IMPACT_INFO	TAIL_BOOM	2397-6/1f	Seq. #
INFLIGHT_IMPACT_INFO	TAIL_BOOM_OBSTACLE_DESC	2397-6/1f	Text
INFLIGHT_IMPACT_INFO	WINDSCREEN	2397-6/1f	Seq. #
INFLIGHT_IMPACT_INFO	WINDSCREEN_OBSTACLE_DESC	2397-6/1f	Text
INFLIGHT_IMPACT_INFO	LOWER_NOSE_GUN-TURRET	2397-6/1f	Seq. #
INFLIGHT_IMPACT_INFO	LOWER_NOSE_OBSTACLE_DESC	2397-6/1f	Text
INFLIGHT_IMPACT_INFO	LANDING_GEAR	2397-6/1f	Seq. #
INFLIGHT_IMPACT_INFO	LANDING_GEAR_OBSTACLE_DESC	2397-6/1f	Text
INFLIGHT_IMPACT_INFO	WING	2397-6/1f	Seq. #
INFLIGHT_IMPACT_INFO	WING_OBSTACLE_DESC	2397-6/1f	Text
INFLIGHT_IMPACT_INFO	EMPENNAGE	2397-6/1f	Seq. #
INFLIGHT_IMPACT_INFO	EMPENNAGE_OBSTACLE_DESC	2397-6/1f	Text
INFLIGHT_IMPACT_INFO	WSPS	2397-6/1f	Seq. #
INFLIGHT_IMPACT_INFO	WSPS_OBSTACLE_DESC	2397-6/1f	Text
INFLIGHT_IMPACT_INFO	FLIR	2397-6/1f	Seq. #
INFLIGHT_IMPACT_INFO	FLIR_OBSTACLE_DESC	2397-6/1f	Text
INFLIGHT_IMPACT_INFO	OTHER_SEQ	2397-6/1f	Seq. #
INFLIGHT_IMPACT_INFO	OTHERS_OBSTACLE_DESC	2397-6/1f	Text

Table 8 – Terrain Impact Kinematics Query

Table	Parameter	Location on Investigation Form	Comment
SUMMARY_INFORMATION	CASE_NUMBER	All pages	Key
SUMMARY_INFORMATION	IS_CRASH = YES		
AIRCRAFT_INFORMATION	MTDS	2397-1/8a	
TERRAIN_IMPACT_INFORMATION	VERTICAL_SPEED	2397-6/2b	FT/MIN
TERRAIN_IMPACT_INFORMATION	VERTICAL_SPEED_DIRECTION	2397-6/b	Up/down
TERRAIN_IMPACT_INFORMATION	VERTICAL_SPEED_ACCURATE	2397-6/2d	T/F
TERRAIN_IMPACT_INFORMATION	GROUND_SPEED	2397-6/2a	KNOTS
TERRAIN_IMPACT_INFORMATION	GROUND_SPEED_ACCURATE	2397-6/2d	T/F
TERRAIN_IMPACT_INFORMATION	FLIGHT_PATH_DEGREE	2397-6/2c	Degrees
TERRAIN_IMPACT_INFORMATION	FLIGHT_PATH_DIRECTION	2397-6/2c	Up/down
TERRAIN_IMPACT_INFORMATION	FLIGHT_PATH_ACCURATE	2397-6/2d	T/F
TERRAIN_IMPACT_INFORMATION	IMPACT_DEGREE	2397-6/2e	Degrees
AIRCRAFT_INFORMATION	CRASH_SITE_GRADE	2397-1/c	L or S
AIRCRAFT_INFORMATION	SLOPE_DEGREE	2397-1/20c	Degrees
TERRAIN_IMPACT_INFORMATION	PITCH_DEGREE	2397-6/2f	Degrees
TERRAIN_IMPACT_INFORMATION	PITCH_DIRECTION	2397	Up/down
TERRAIN_IMPACT_INFORMATION	ROLL_DEGREE	2397	Degrees
TERRAIN_IMPACT_INFORMATION	ROLL_DIRECTION	2397	Left/right
TERRAIN_IMPACT_INFORMATION	YAW_DEGREE	2397	Degrees
TERRAIN_IMPACT_INFORMATION	YAW_DIRECTION	2397	Left/right
IMPACT_EFFECTS_INFORMATION	VERTICAL_G	2397-6/4a	Gs
IMPACT_EFFECTS_INFORMATION	LONGITUDINAL_G	2397-6/4b	Gs
IMPACT_EFFECTS_INFORMATION	LATERAL_G	2397-6/4c	Gs
IMPACT_EFFECTS_INFORMATION	VERTICAL_DIRECTION	2397-6/4a	Up/dn
IMPACT_EFFECTS_INFORMATION	LONGITUDINAL_AREA	2397-6/4b	Fore/aft
IMPACT_EFFECTS_INFORMATION	LATERAL_DIRECTION	2397-6/4c	Left/Right
AIRCRAFT_INFORMATION	SURVIVABILITY	2397-1/11	S/PS/NS/AcL

It was common to find blank cells, particularly for the VERTICAL_VELOCITY and the attitude angles of the impact data. For these blank cells, the SUMMARY was reviewed and the blank cells were changed to zero where the summary or other data supported that the value was actually zero rather than unknown.

These changes were reviewed[5] and, in some cases, modified after discussions with a former military pilot and aerodynamicist who reviewed the mishap summaries and looked at the kinematic data. For cases where the information was complete but inconsistent, the mishap was excluded.

A second consistency check was applied to the terrain impact data. The FLIGHT_PATH, plus the TERRAIN_ANGLE, were compared to the IMPACT_ANGLE. If the two values agreed within 15 degrees, the data were deemed consistent. Where they differed, the SUMMARY was reviewed. In only a few cases was sufficient information available to resolve the inconsistency or to fill in missing information. Mishaps with incomplete data were excluded from further analysis.

The terrain impact records that passed both consistency checks and had all data present were tagged with an identifier. The identifier designated the crash to be usable. Likewise, the inflight impact records that passed the consistency check and had all data present were tagged with an identifier to indicate that the record is usable in the analysis.

3.2.1 – Kinematic Analysis

The kinematic analysis focuses on the dynamic aspects of the crashes. In particular the velocities, impact angles, and attitude angles are studied. Prior to performing this analysis the crashes were grouped according to whether the crash occurred directly to the terrain or an obstacle was struck prior to the terrain impact. The number of crashes in each group are also reported.

3.2.1.1 – Create Data Sets and Plots for Cumulative Velocities

While analyzing both the inflight impacts and the terrain impacts had the potential to provide significantly more insight into the crashes of aircraft and the response of the aircraft to those crashes, the presence of two data sets both enhances and complicates the analysis. Considering the inflight impact data separately created a multiplicity of impact possibilities. To address this multiplicity, an Impact Type has been assigned to each record. Table 9 presents these impact type codes along with an explanation describing the intent of the type.

Table 9 – Codes and Explanations for Impact Types

Impact Type	Code	Description
Terrain	T	Aircraft-impacted-only terrain.
Combined Terrain	CT	Aircraft-impacted inflight obstacle followed by terrain. This code only used for pre-July 1977 mishaps of the AH-1 and the OH-6. Mishaps coded “CT” were not analyzed.
Inflight	I	Only the inflight impact created damage. The aircraft was subsequently landed, so there was no terrain impact. These mishaps were not analyzed.
Inflight plus Terrain	IT	Both an inflight impact and a terrain impact occurred.

This increase in the multiplicity of event scenarios led to a corresponding increase in the multiplicity of usable data sets. However, the crashes designated CT and I were not included in the analysis because

[5] Personal communications: Jack Cress, Vortechs Helicopter Analytics, North Monterey County, CA. Mr. Cress is a helicopter aerodynamicist and retired military helicopter pilot.

these crashes did not contribute information of interest to the study. Consequently, another parameter was created to identify the usability of the event for analysis. Table 10 presents the list of codes for the "Usability for Analysis" parameter.

The events with "Usability for Analysis" codes of *T* and *IT* are used for the subsequent analyses. These crashes have complete data records and are clearly relevant. Because it is desirable to include as many events as possible, a protocol was developed to include those events for which data for only one of the impacts were recorded. The events coded *I* are complete for the initial impact and can provide useful information on the kinematics of aircraft striking obstacles. The *I* events were combined with the inflight data records for the *IT* events; this combination does not risk distorting the conclusions drawn regarding inflight impacts. Arguably, the incidents coded *TA* might be combined with the pure Terrain impacts (*T*) for analysis. However, the range of aircraft attitudes following the initial impact was expected to be wider than the range of aircraft attitudes for impacts directly to the terrain. Consequently, the conclusions about terrain impacts could be altered by the inclusion of this data.

Table 10 – "Usability for Analysis" Codes and Descriptions

Usability for Analysis	Code	Description
Terrain	*T*	Aircraft impacted only terrain and the mishap is usable.
Inflight	*I*	Only the inflight impact is usable. Either: • The aircraft only sustained damage from the inflight impact and subsequently landed, or • The subsequent terrain impact data were incomplete or unusable.
Terrain after Inflight	*TA*	An inflight impact occurred and a terrain impact occurred. However, either: • No inflight data were recorded, or • The inflight record is not usable.
Inflight plus Terrain	*IT*	Both an inflight impact and a terrain impact occurred and both records are usable. In this type of mishap, there are two usable records for each aircraft, one for the inflight impact (*IT-I*) and one for the terrain impact (*IT-T*).

The decision on combining the different impact data sets (*T*, *TA*, *I*, and *IT*) was addressed prior to creating the cumulative velocity data sets for plotting. The mishaps coded *IT* have two data sets associated with them: one set describes the inflight impacts (designated *IT-I*) and another set describes the terrain impacts following the inflight impact (designated *IT-T*). The inflight impacts are divided into three data sets: *I*, *IT-I*, and *TA*. The terrain impacts are divided into two data sets: *T* and *IT-T*. While having data available on the inflight impacts that precede some terrain impacts has the potential to provide a clearer understanding of these mishaps, another result is that the data set for the combination of a particular impact type and aircraft type may become rather small. Table 11 presents the numbers of each impact type by aircraft. Having identified the crashes as to their separate types, the option is available to combine some data sets back together. The important consideration is that the events are sufficiently similar in nature that combining them will still result in meaningful conclusions. For the cumulative velocity analysis, the inflight only (*I*) impacts were combined with the inflight data set for the mishaps coded *IT-I*. Because the inflight impact is the first event in the sequence, the combination of the *I* data set with the inflight portion of the *IT* data set would serve to improve the statistics of the combined data set without changing the analysis outcome of the velocity and angle distributions. Likewise, the impacts

coded *IT-T* were combined with those coded *TA (IT&TA)*. Both of these categories are crashes with terrain following an impact with an inflight obstacle. The difference is whether or not the data for the inflight impact are usable. Consequently, these two data sets should also be combinable without compromising the conclusions about the terrain phase of the impact.

Table 11 – Number by Type of Usable Crashes for Each Aircraft Data Set

Aircraft	Usable Terrain Mishaps [Code = *T*] (#)	Incomplete Inflight & Usable Terrain [Code= *TA*] (#)	Usable Inflight with Only Inflight Data [Code = *I*] (#)	Inflight & Terrain, Both Data Sets Usable [Code = *IT*] (#)	Usable Records (#)
AH-1	68	11	8	15	102
AH-64	42	3	12	21	78
CH-47	21	2	2	1	26
OH-6	29	2	2	1	34
OH-58AC	*80*	*14*	*23*	*26*	*143*
OH-58D	*33*	*7*	*4*	*6*	*50*
OH-58	113	21	27	32	193
UH-1	104	18	19	33	174
UH-60	39	11	14	15	79
C-23	2	0	0	0	2

Note: OH-58AC and OH-58D are subsets of OH-58.

The plotting of cumulative velocities was done in using spreadsheet software. A copy was made of the file which contains the data from the terrain impact query for each aircraft type. The data for use in the cumulative velocity plots was copied from the query matrix to a new worksheet. The data each crash included: vertical speed, ground speed, vertical, longitudinal, and lateral velocities in the aircraft reference frame, survivability, and usability code. This new worksheet was used to create tables of data for plotting purposes.

The data sort function was applied to group the data records by usability code (i.e., all of the records coded *IT-T* and *TA* were grouped together {labeled *IT&TA*}, and all crashes coded *T* were grouped). To plot the cumulative velocity for vertical velocity in the aircraft reference frame, all of the values coded *T* for this velocity were copied over to another area of the worksheet. In the column next to these values, the absolute value function was applied to each value so that a column of all positive values was created. Next to these values, the corresponding values for the survivability and the impact usability code were copied. This matrix was then sorted in ascending order by the absolute value of the velocity. The next column to the right was filled with a series of integers from one to the number of rows in the data set. In the next column, each of these integers was divided by the total number of impacts in the data set (i.e., the last integer). Formatted as a percentage, this column contains the cumulative percentile for each impact.

The first data set for plotting contains all the mishaps with the selected usability codes regardless of the survivability code. The survivability codes are: S=1 for survivable, S=2 for partially survivable, and S=3 for non-survivable. A few crashes were not assigned survivability codes; these are grouped with the non-survivable crashes for velocity analysis purposes.

The entire plotting table was then copied to the right on the worksheet and sorted according to the survivability codes. The non-survivable (S=3) and the non-coded records were cut off to form a data set for plotting survivable and partially survivable crashes (labeled “S=1&2”).

This process for creating plotting tables was repeated for the other four velocities and for the other impact type. For the terrain impacts, there were 20 data sets for each aircraft type: five velocities multiplied by two impact type groups, multiplied by two survivability levels. One impact group for the terrain set was all *T* crashes and the other was *IT-T* combined with *TA* crashes. Cumulative velocity plots for the S=1&2 crashes can be found in Appendix A. Plotting tables were also prepared for S=all crashes.

A similar table preparation process was applied to the inflight impacts. Here the impact types *I* and *IT-I* were grouped together. Consequently, there are ten inflight impact plot tables: five velocities multiplied by two survivability levels. The plots for the ground speed and vertical speed (ERF) are presented in Appendix L.

Table 12 presents the number of crashes considered usable for each plot. It is readily apparent that some of these plots are based on very small data sets. In particular, the inflight datasets for the OH-6, the OH-58D, and the CH-47 are very small.

Table 12 – Number of Crashes in Each Cumulative Velocity Plot

	T S=all	T S=1&2	IT-T & TA S=all	IT-T & TA S=1&2	IT-I & I S=all	IT-I & I S=1&2
AH-1	68	59	26	21	23	20
AH-64	42	32	24	19	33	26
CH-47	21	17	3	2	3	1
OH-6	29	28	5	3	5	3
OH-58AC	79	66	40	31	47	37
OH-58D	33	27	13	11	9	7
UH-1	103	83	49	42	50	44
UH-60	39	26	26	15	29	17
C-23	2	0	0	0	0	0

3.2.1.2 – Frequency of Crash Types

Considering the frequency of the two crash types reveals a meaningful trend among the aircraft types. Looking at the numbers for all crashes by aircraft type and by crash type, Table 13 reveals a difference between the earlier generation of aircraft and the later generation. From this analysis of the data, it is evident that the later generation experiences more post-obstacle crashes than the earlier generation. The OH-58A/C could be assigned to first generation on the basis of the “old” rotor system and the D to the second generation based on the “new” rotor system, but both variants have roughly the same level of structural crashworthiness. There has been an ongoing discussion in the crashworthiness community as to

why the new generation of aircraft with greater crashworthiness have not shown a greater reduction in severe injuries and fatalities. One reason proposed has been that the mission profiles have also changed dramatically. The results in Table 13 suggest that a partial explanation may be found in the frequency of post-obstacle crashes experienced by the two generations. Despite its crashworthy design, the UH-60 has been noted by Shanahan[1] as having a high rate of severe injuries. It is interesting to note that, in Table 13, the UH-60 has the highest frequency of post-obstacle crashes in the group.

It has also been stated by Mapes[6] that the CH-47 is a particularly survivable aircraft; Table 13 indicates that the CH-47 experiences the lowest frequency of post-obstacle crashes among the aircraft analyzed.

Table 13 – Comparison of Crash Type Frequencies

	T Crashes (no.)	IT&TA Crashes (no.)	Fraction IT&TA (percent)
AH-1	68	26	27.7
UH-1	103	49	32.2
"1ST Generation"	171	75	30.5
AH-64	42	24	36.4
UH-60	39	26	40.0
"2ND Generation"	81	50	38.2
OH-58AC	79	40	33.6
OH-58D	33	13	28.3
CH-47	21	3	12.5
OH-6	29	5	14.7

3.2.2 – Cumulative Velocity Plots for All Aircraft Combined

Cumulative velocity plots (also known as cumulative velocity frequency curves) for rotorcraft were used in the 1971 edition of the *Aircraft Crash Survival Design Guide*[7] (ACSDG) to present the velocity distribution of the impacts. For comparison purposes, the ACSDG curves were digitized and included the cumulative velocity plots of all aircraft types combined. The ACSDG contained two plots in the aircraft reference frame (AcRF) one for longitudinal velocity and one for vertical velocity. The cumulative velocity plot has become an important tool for summarizing the fundamental character of crashes and for

6 Mapes, Col. P., Kent, LTC. R., & Wood, LTC. R., *DOD Helicopter Mishaps FY85-05: Findings and Recommendations*, presented at the American Helicopter Society Forum 64, May 2008, document numbers AFRL-WS 07-0731, AFRL-WS 07-1099 and AFRL-WS 07-1100.

7 Turnbow, J.W., et al., *Crash Survival Design Guide*, USAAMDRL Technical report 71-22, prepared by Dynamic Science Engineering Operations, Division Marshall Industries, for the US Army Air Mobility Research and Development Laboratory, Ft. Eustis, VA, October 1971.

setting design guidelines on crashworthiness. In the interest of continuity, this report also uses the cumulative velocity plot as a tool for characterizing crash kinematics.

The cumulative velocity plots for all aircraft were created by combining the data set for each aircraft into one large data set for each of the five velocities. The entire data set was then sorted in ascending order and the cumulative percentile for each point calculated based on the total number of data points. In the following paragraphs, the plots for the two velocities in the ERF are discuss prior to discussing the plots for the velocities in the AcRF.

The first plot (see Figure 3) presents the cumulative frequency for the vertical speed and for the ground speed; both in the earth reference frame (ERF). This plot is for survivable and partially survivable crashes (as indicated by the legend notation "S= 1&2"). The plot reveals that at any given percentile, the ground speed is generally higher than the vertical speed.

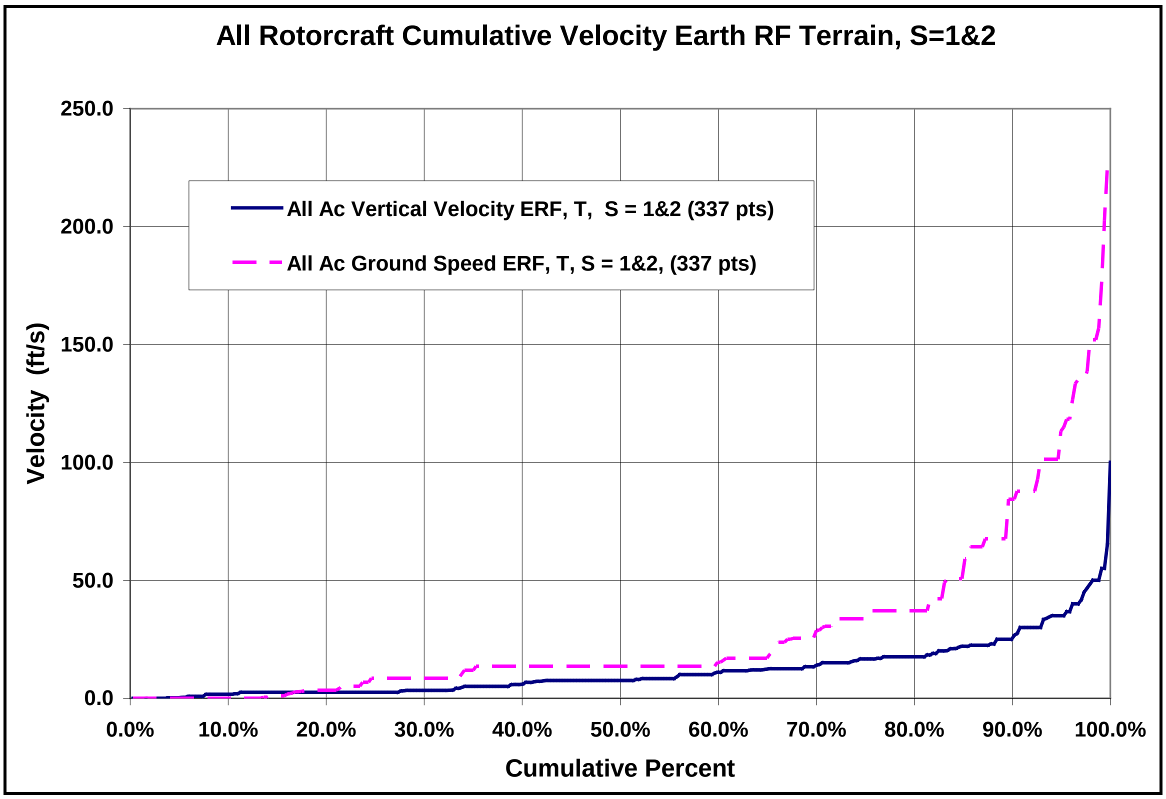

Figure 3 – Cumulative Velocity for T Crashes in ERF

Shifting to the aircraft reference frame, similar plots were created for velocities along the three principle axes of the aircraft. For two of these plots, there is a corresponding curve in the 1971 ACSDG that can be superimposed onto terrain impact data from the current study. Figure 4 presents the cumulative velocity plot for vertical velocity in the aircraft reference frame. The reader will observe that at the lower percentiles, the velocity values are significantly higher in the older study. In looking for the

considerations that would explain these differences, the author referred back to the 1971 ACSDG[8]. The kinetics curves were based on mishaps that occurred between 1 July 1960 and 30 June 1965. Some additional data on subsequent mishaps was also incorporated. The text in Section 1.1.1.2 of the ACSDG states that "The accident cases selected were limited to those in which one or more of the following factors applied: (a) substantial structural damage, (b) post-crash fire, (c) personnel injuries, and (d) at least one person survived the crash. Mid-air collisions and other accidents resulting in catastrophic uncontrolled free falls from altitudes of a hundred feet or more were not considered." In Section 1.1.1.3 of the ACSDG, the report states that 563 rotary-wing and 92 fixed-wing accidents were reviewed, but only 373 total cases were included for determining the impact conditions. The conditions for including a crash in this study are described in Section 3.1.1 of this report. This study includes any mishap in which there was measurable damage to the aircraft based on the description in the narrative and the fact that the mishap was rated as either a category A or B mishap.

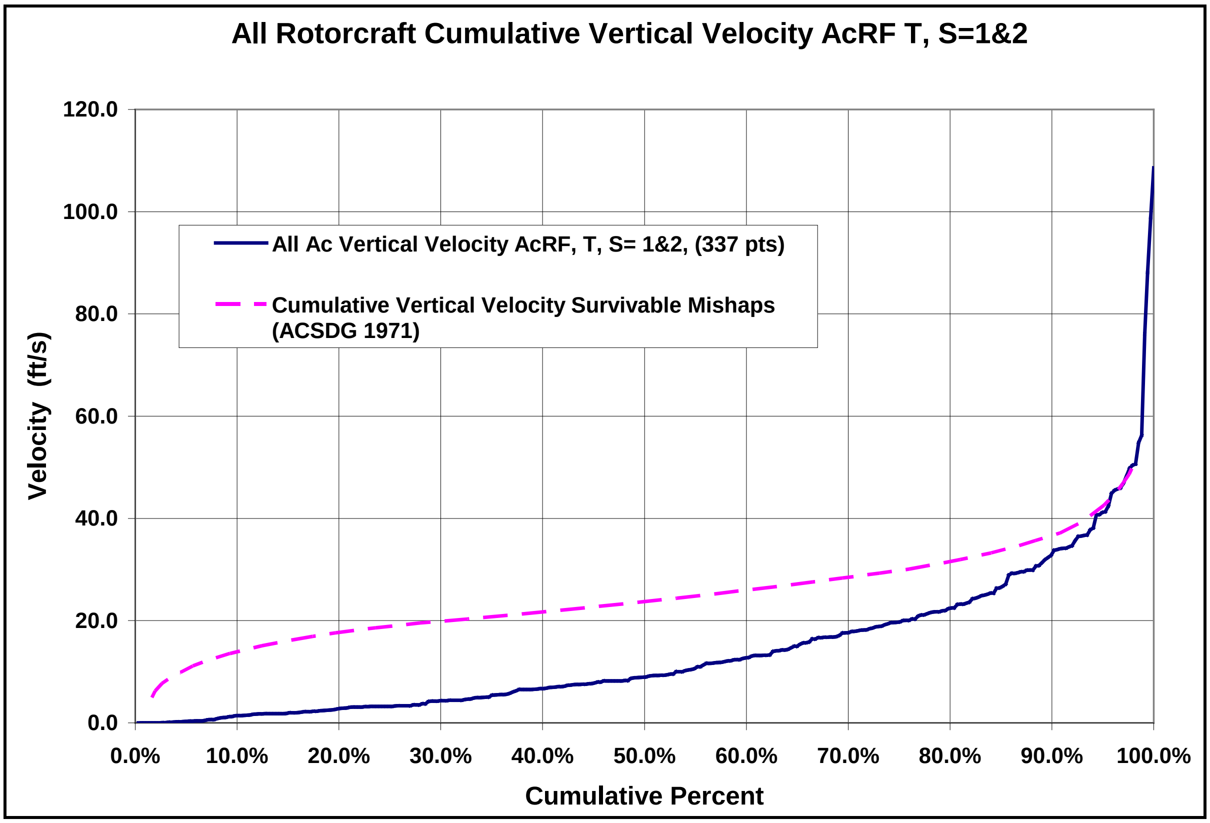

Figure 4 – Cumulative Vertical Velocity for Helicopters Terrain Crashes

The cumulative frequency plot for longitudinal velocity is shown in Figure 5. The corresponding cumulative plot from the 1971 ACSDG is plotted over the longitudinal curve for comparison. As with the

[8] Turnbow, J.W. et al., USAAVLABS Technical Report 70-22, *Crash Survival Design Guide*, Revised August 1969, prepared for U.S. Army Aviation Materiel Laboratories, Fort Eustis, VA, by Dynamic Science, a Division of Marshall Industries, Phoenix, AZ. August 1969.

vertical velocity, the lower percentile velocities were higher in the earlier study than in the current study. However, at about the 83rd-percentile event, the velocities for the new study crossover the prior study and from there on are significantly higher. Once again, all crashes in this plot are survivable or partially survivable (S=1&2).

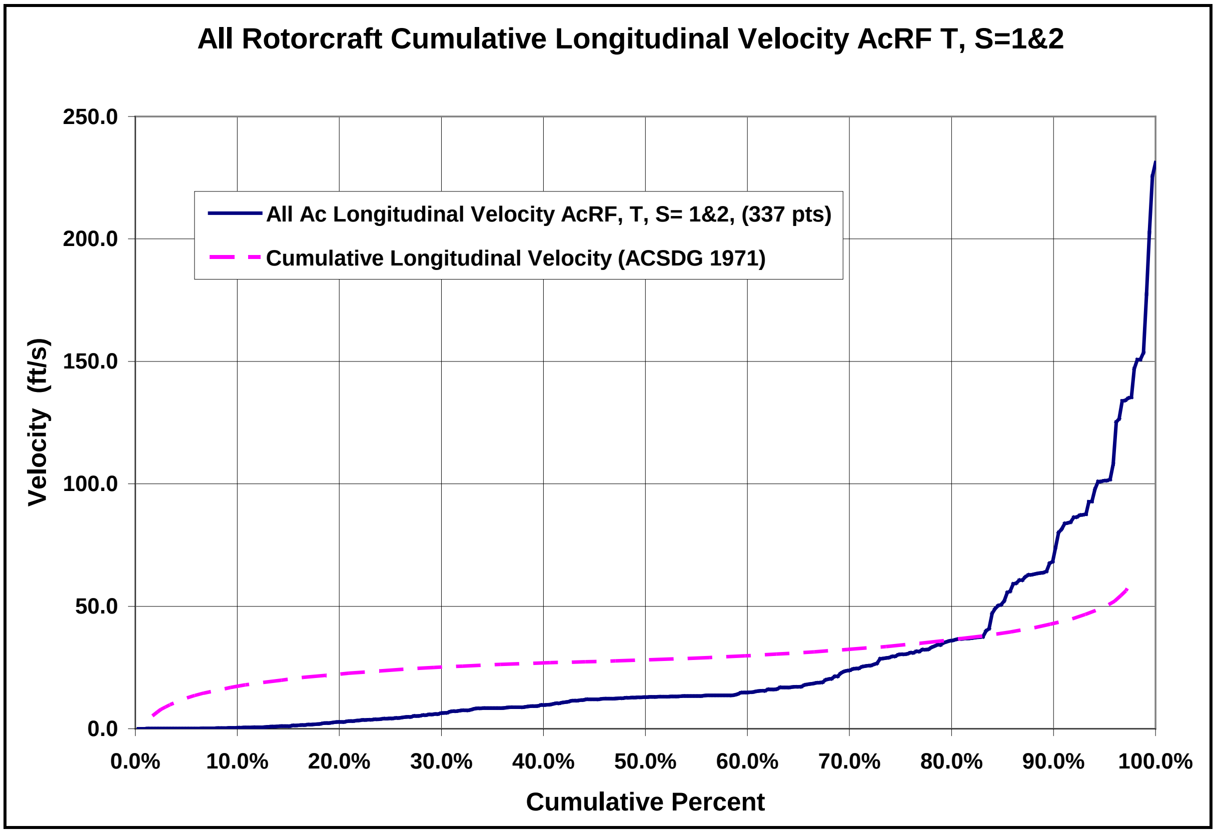

Figure 5 – Cumulative Longitudinal Velocity for Helicopter Terrain Crashes

The cumulative frequency for lateral velocity from this study is presented in Figure 6. No corresponding curve existed in the earlier ACSDG; thus, there is no comparison curve provided in Figure 6. In general, the lateral velocities are much lower than either longitudinal or vertical impact velocities. This result is consistent with the fact that the impact attitude angles (see following discussion of impact attitude angles) cluster around the normal aircraft attitude (i.e., pitch, roll, and yaw equal to zero).

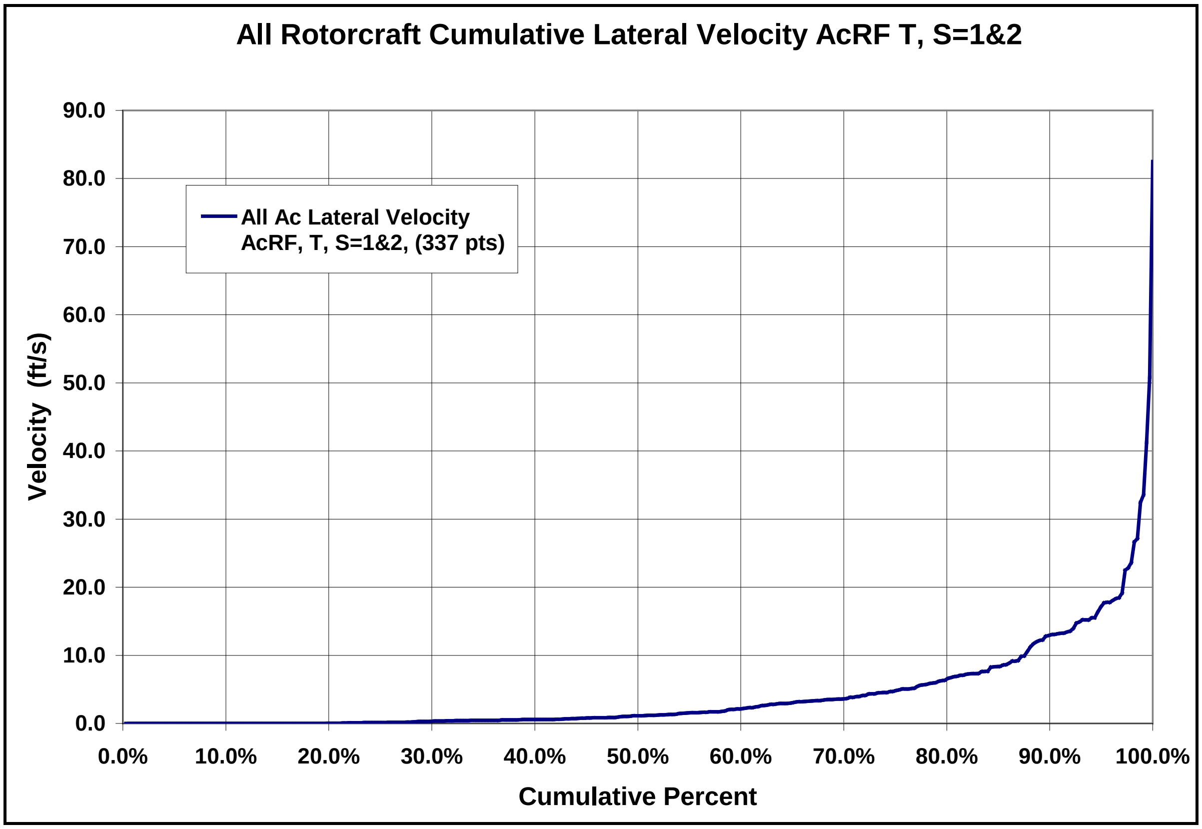

Figure 6 – Cumulative Lateral Velocity (AcRF) for Helicopter Terrain Crashes

A corresponding set of plots exists for the crashes where the terrain impact follows a collision with an obstacle above ground level. Plots of the ground speed and the vertical velocity in the ERF are presented in Figure 7. This curve corresponds to Figure 3 for impacts directly into terrain. The study used as a source by the 1971 ASDG did not differentiate between impacts directly into terrain and those that followed collisions with obstacles. Consequently, there is no curve from the earlier ACSDG corresponding to Figure 7.

The cumulative velocity curves for longitudinal velocity, vertical velocity, and lateral velocity in the AcRF after an obstacle impact are presented in Figure 8, Figure 9, and Figure 10. There is no ACSDG reference curve for these curves, because this type of crash was not separately analyzed in the 1971 ASDG.

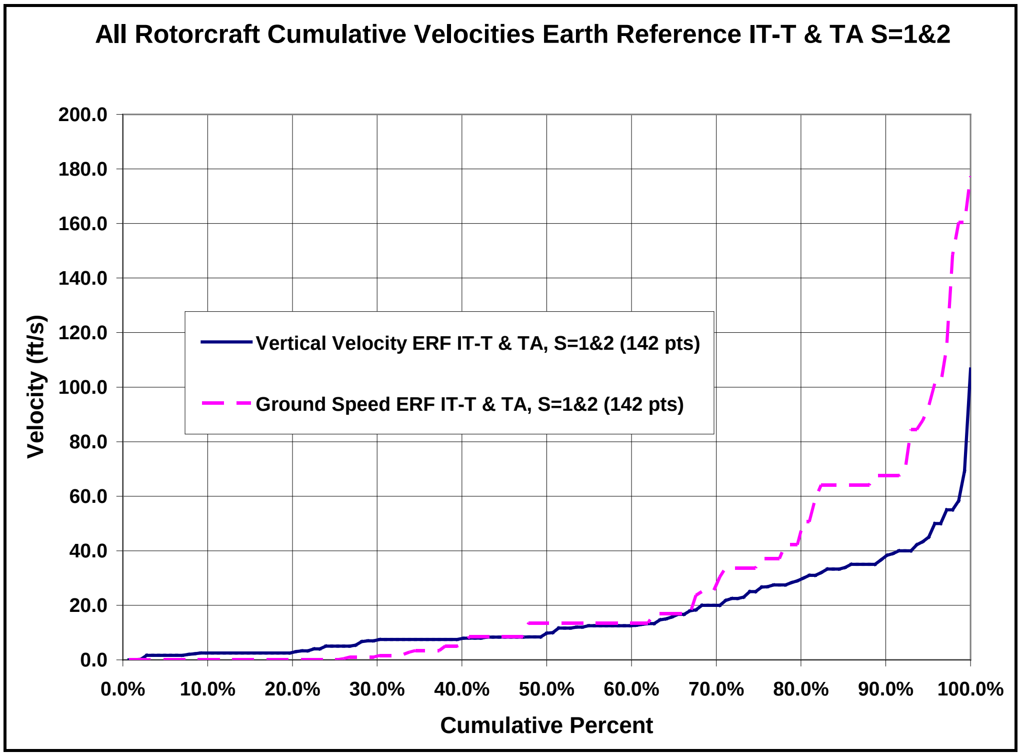

Figure 7 – Cumulative Velocities (ERF) for Crashes Following Obstacle Impacts

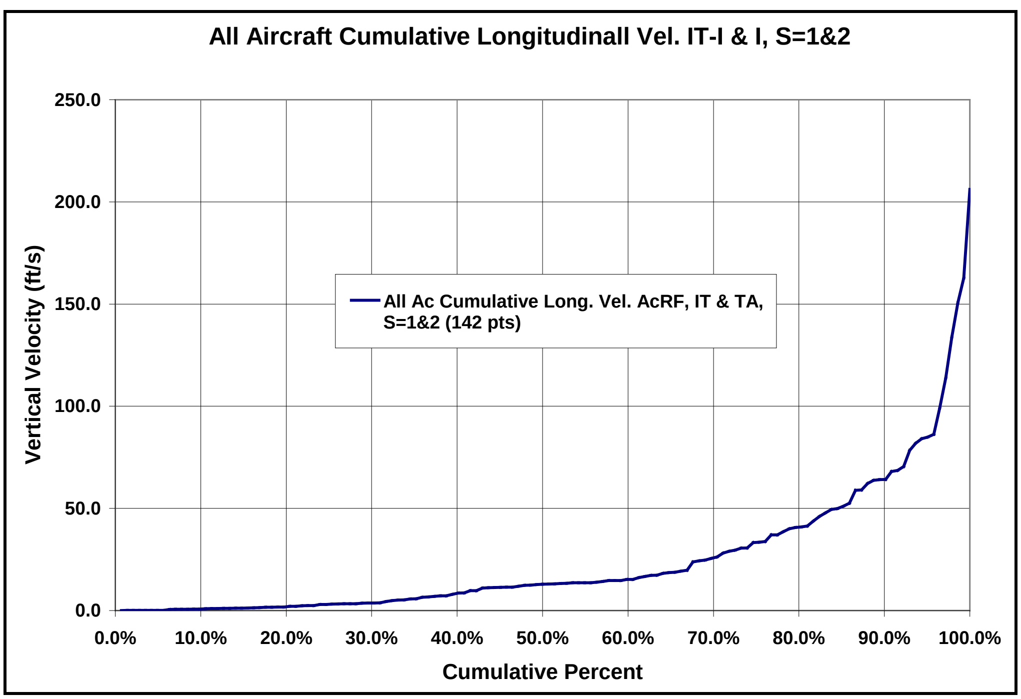

Figure 8 – Cumulative Longitudinal Crash Velocity (AcRF) after Obstacle Impact

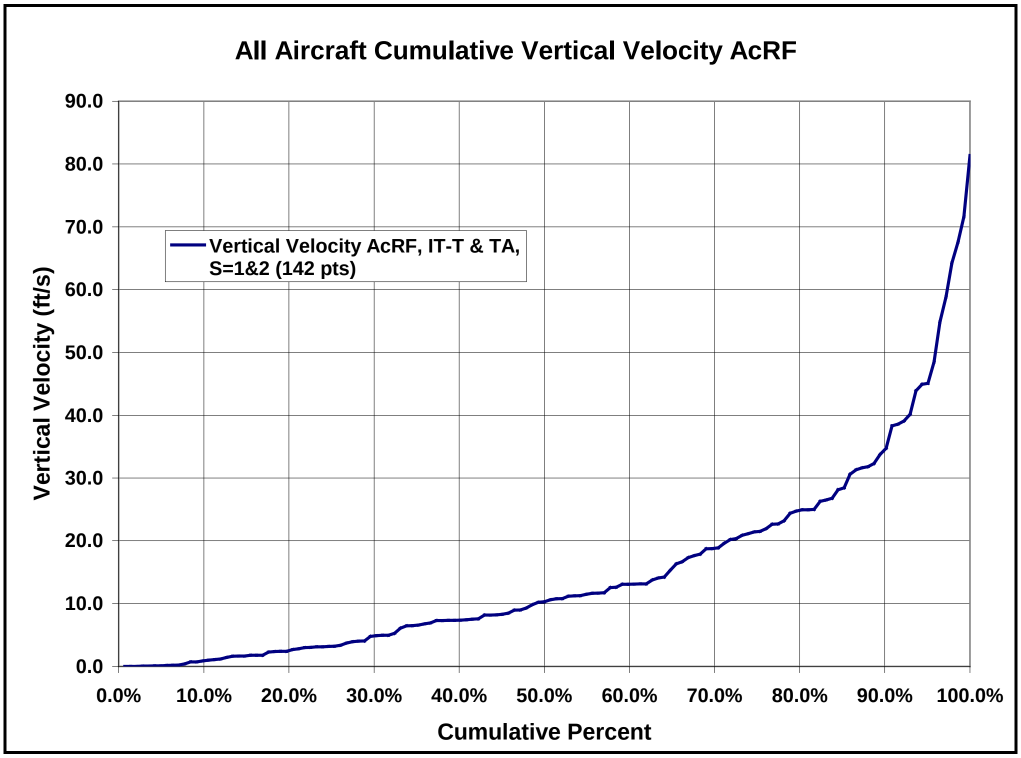

Figure 9 – Cumulative Vertical Crash Velocity AcRF after Obstacle Impact

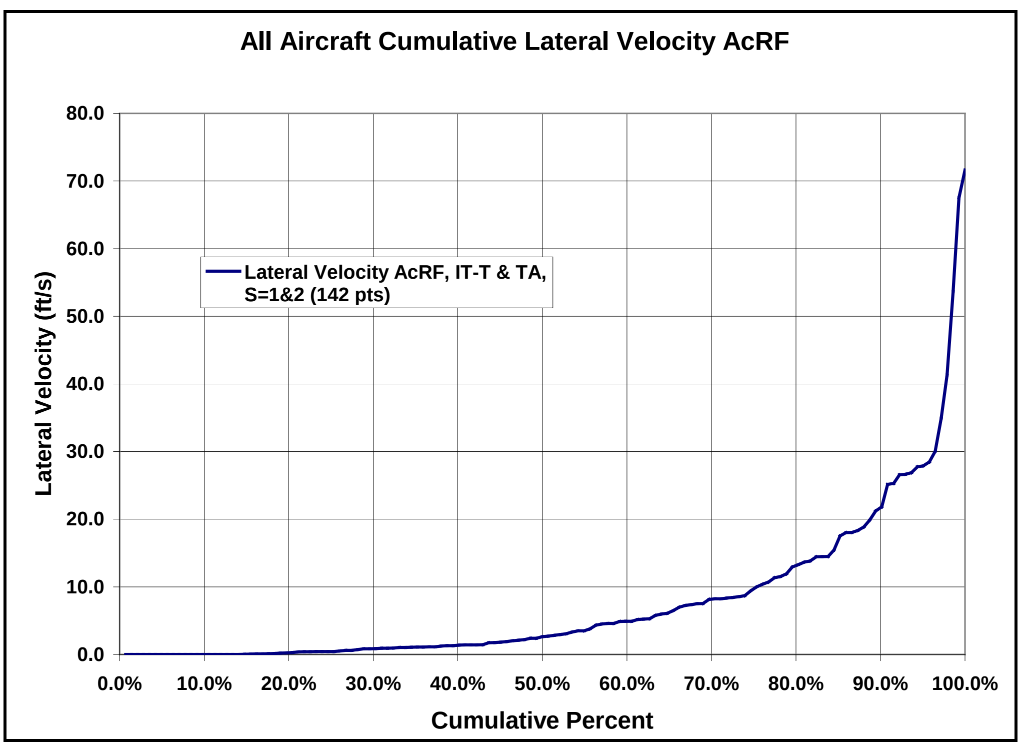

Figure 10 – Cumulative Lateral Crash Velocity (AcRF) after Obstacle Impact

3.2.3 – Comparison of Impact Velocities Post-Obstacle Strike to Those with No Prior Impact

The availability of data on the impacts between aircraft and obstacles above ground level not only provides a new set of impact data, but these data also provide a means of identifying those terrain impacts that were preceded by an obstacle impact. This ability to differentiate the two sets of crashes enables this study to investigate the effect of the obstacle strike on the impact kinematics. As a first step, the cumulative velocity curves for each set of data can be compared. The two velocities recorded in the ERF, the ground speed and the vertical velocity, were compared (Figure 11 and Figure 12). Looking first at the ground speed, the plot indicates that for the higher speed mishaps (above the 85th-percentile), a prior impact with an obstacle reduces the ground impact speed compared to the same percentile crash directly into the terrain. The trend is reversed for the vertical velocity over much of the percentile range. A prior impact with an obstacle leads to higher vertical impact velocities.

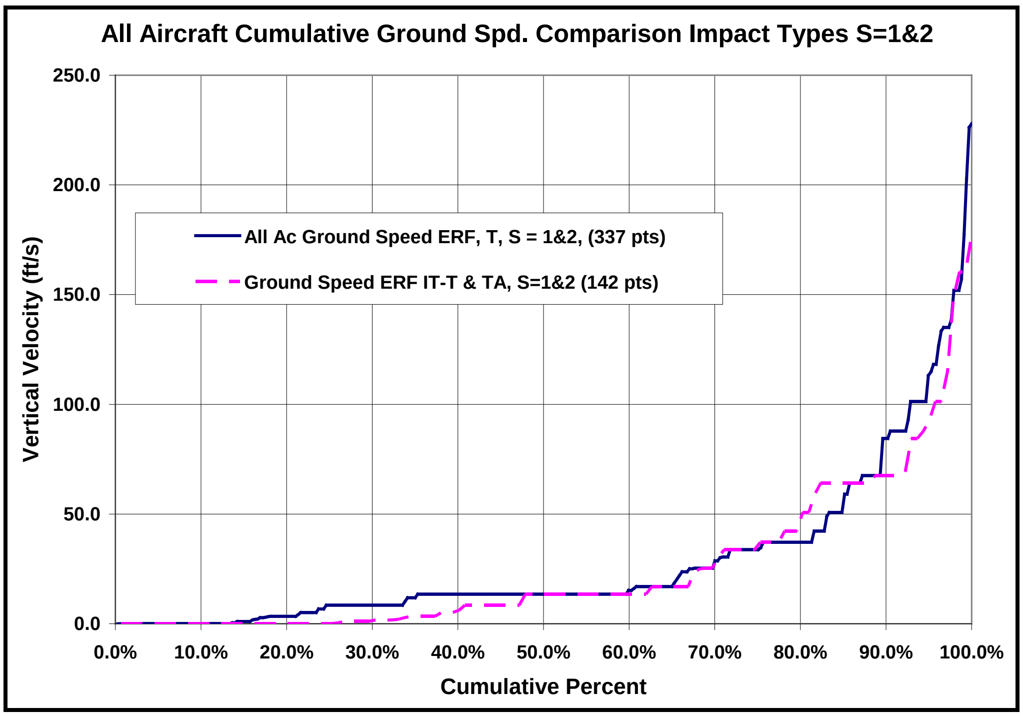

Figure 11 – Comparison of Ground Speeds (ERF) for Obstacle and Non-obstacle Crashes

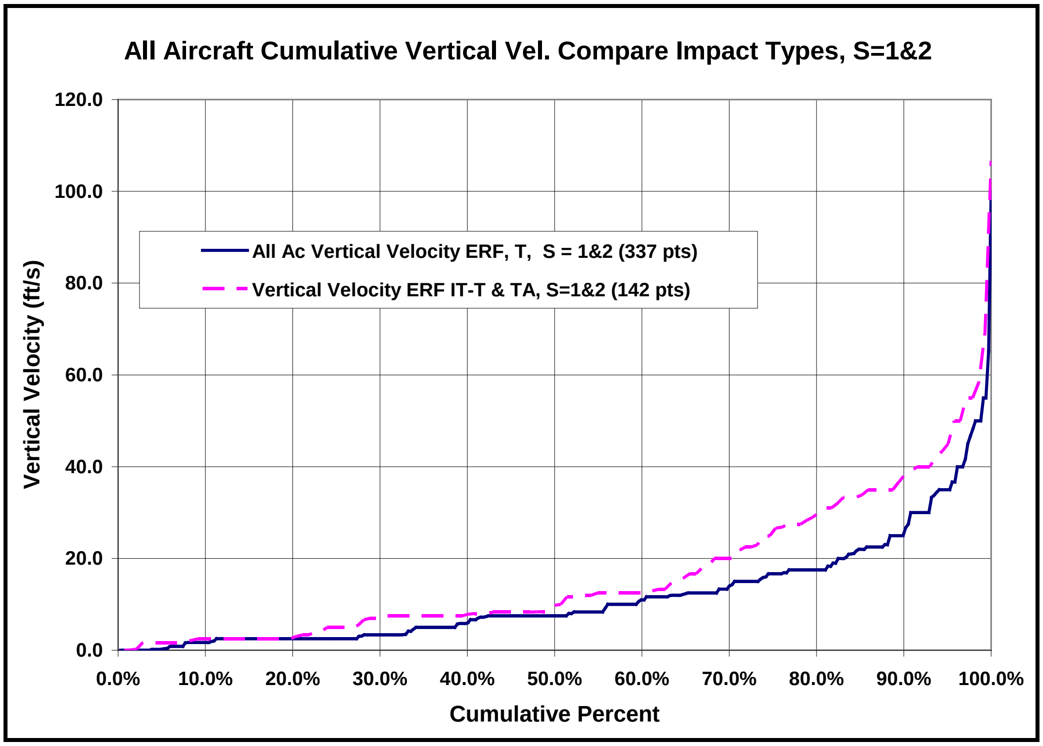

Figure 12 – Comparison of Vertical Velocity (ERF) for Obstacle and Non-obstacle Crashes

3.2.4 – All Aircraft ERF Velocities – Difference by Crash Type

The hypothesis that these two ground speed and vertical speed populations differ according to the type of crash was tested for statistical validity. The hypothesis was not supported statistically (Table 14). Neither the median values nor the mean values for the vertical speed differ sufficiently to be statistically significant. The Mann-Whitney Test (M-W Test) was applied to the medians; where the value of p must be less than or equal to 0.05 in order to be 95-percent confident that the medians of the two populations are actually different. Likewise, the difference between the means does not achieve statistical significance. The statistical test applied here is the Two Sample T Test (TST Test)—again, the value of the parameter p must be less than 0.05 in order for there to be a 95-percent confidence that the means of the two populations are actually different. Even if one of these two parameters had indicated a statistical difference, the actual values do not differ by an amount that has practical consequences. The statistical test on the ground speeds of the two populations had a different outcome. The M-W Test actually indicates that the medians differ although the calculated values are equal in 5 digits. Consequently, there is no practical difference in the medians. The means differ by 2.9 ft/s, which correspond to a difference in kinetic energy of 25 percent. Although this amount of kinetic energy has practical consequences, the statistical test does not confirm that the means actually differ.

Table 14 – Statistical Comparison of the ERF Velocities for T and IT&TA Type Crashes

Velocity	Median T Crashes (ft/s)	Median IT&TA Crashes (ft/s)	p value M-W Test	Mean T Crashes (ft/s)	Mean IT&TA Crashes (ft/s)	p value TST Test
Vertical Speed	9.00	9.90	0.075	14.00	16.5	0.118
Ground Speed	13.500	13.500	0.044	28.3	25.4	0.429

Comparisons may also be made for the velocities along the three aircraft axes. Impacting an obstacle influences the vertical velocities in only the highest 10 percentile crashes (Figure 13). The vertical velocities of the impact following obstacle strikes are higher than those for direct terrain impacts, but the plot reveals little difference between the two types of impacts (Figure 14). The two curves are similar up to the 65th-percentile, where they begin to separate, then subsequently cross and end up having similar values in the high 90th percentiles. The two lateral velocity sets (Figure 15) show the only clear difference within this group of comparisons. The lateral impact velocities for crashes following inflight obstacle strikes are notably higher than the lateral velocities for crashes directly into the terrain.

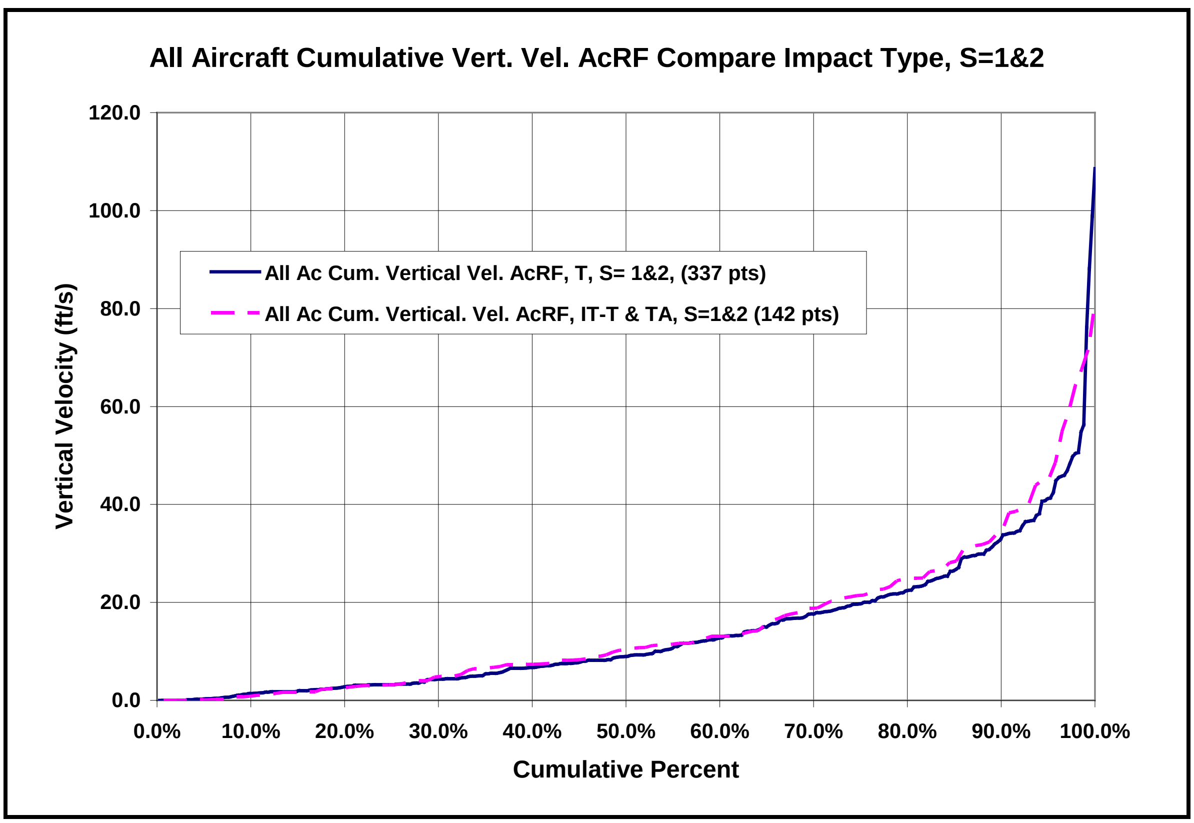

Figure 13 – Comparison of Vertical Velocity (AcRF) for Post-obstacle and Terrain Crashes

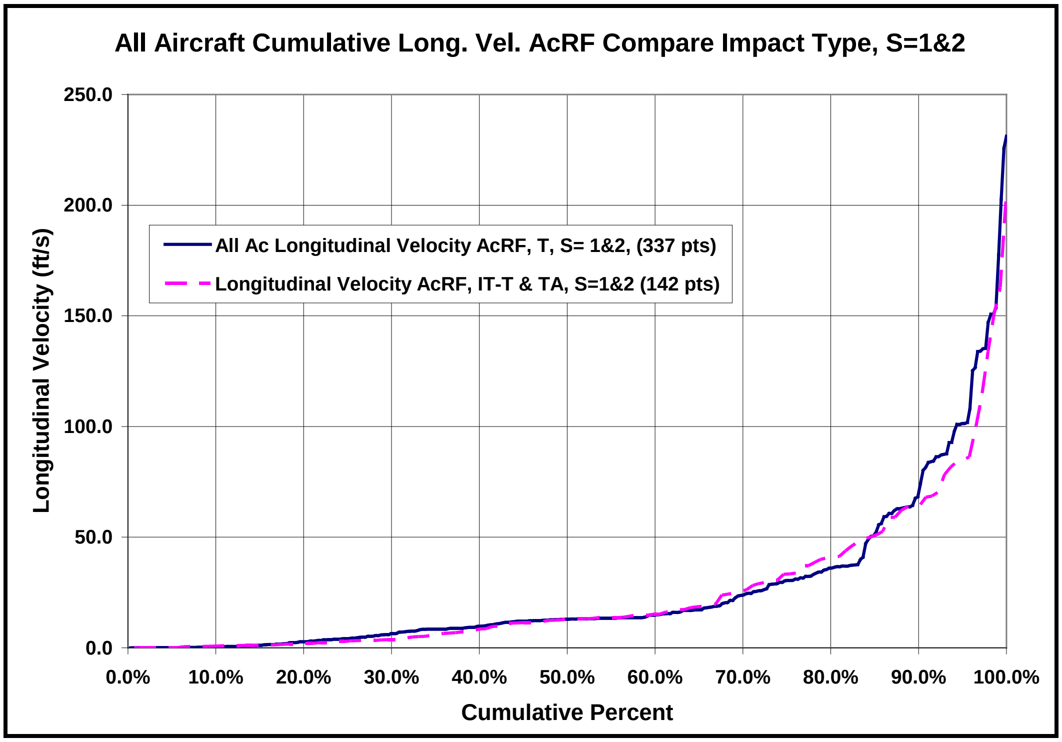

Figure 14 – Comparison of Longitudinal Velocity (AcRF) for Obstacle and Non-Obstacle Crashes

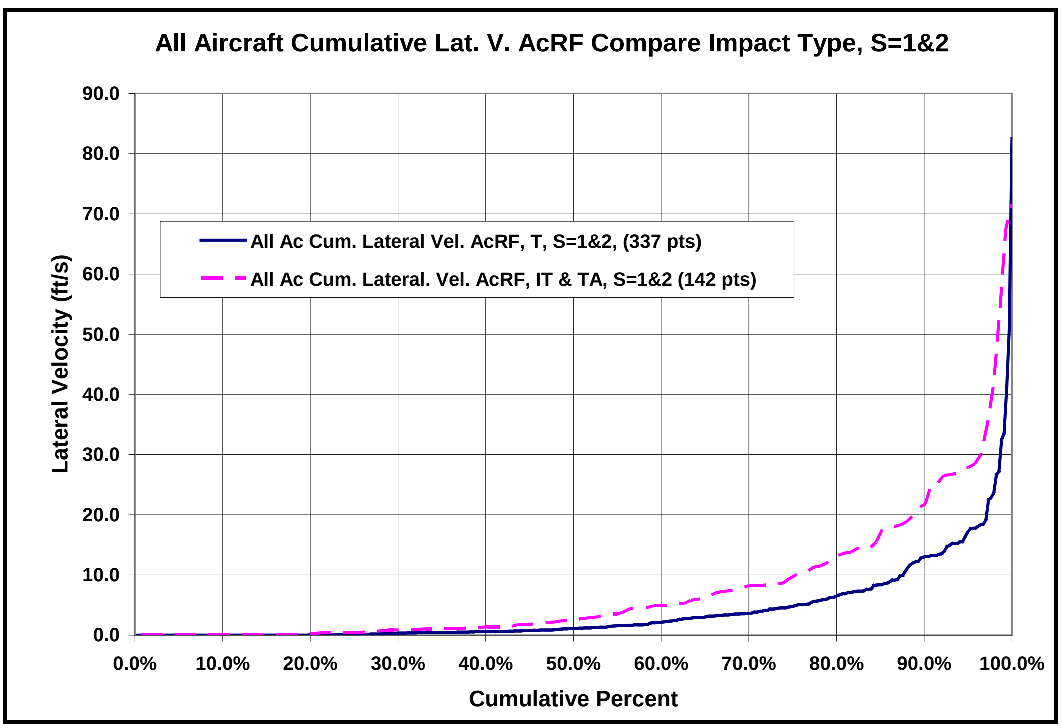

Figure 15 – Comparison of Lateral Velocity (AcRF) for Obstacle and Non-Obstacle Crashes

To quantify the information that is evident in Figure 15, the combined velocity data for all aircraft was divided into 10 percentile increments. The average velocity and standard deviation in each increment were calculated (Table 15). The process was applied to both the terrain crash data (T) and to the crash data following obstacle strikes. In each case above the 50th percentile, the average lateral velocity for the crashes following an obstacle strike are higher than those for the same percentile group for crashes directly into the terrain. Viewed in terms of the amount of kinetic energy to be managed, these velocity differences are of practical significance.

Table 15 – Average Lateral Velocity Comparison between Impact Types

Percentile Range	Average Lateral Velocity within Range for Terrain (T) Crashes (ft/s) [StDev]	Average Lateral Velocity within Range for Terrain Crashes After Obstacle Strike (IT & TA) (ft/s) [StDev]
50-60	1.5 [0.3]	3.7 [0.8]
60-70	3.0 [0.4]	6.4 [1.1]
70-80	4.9 [0.8]	9.9 [1.6]
80-90	8.9 [2.0]	16.5 [2.6]
90-100	21.7 [13.7]	35.7 [15.9]

For plotting the basic cumulative velocity curves of each aircraft type, the curve for each of the five velocities was created on a single plot along with the cumulative velocity curve for all aircraft as a reference curve. A set of five curves was created for the T crashes associated with each aircraft type and another set of five curves was created for the IT&TA crashes. These 80 plots appear in Appendix A of the report.

Comparing the vertical velocity for the direct terrain impacts (*T*) to those for the terrain impacts following an inflight impact (*IT & TA*) suggests that the vertical velocity is higher for crashes following an inflight impact. As an example, Figure 16 presents the ground speed and vertical speed cumulative curves for the UH-60. The impact ground speed for crashes following an inflight impact (*IT & TA*) are generally lower than the ground speed for an impact directly with the terrain (*T*). Thus, it can be hypothesized that an inflight obstacle impact prior to the terrain impact influences the kinetics of the terrain impact.

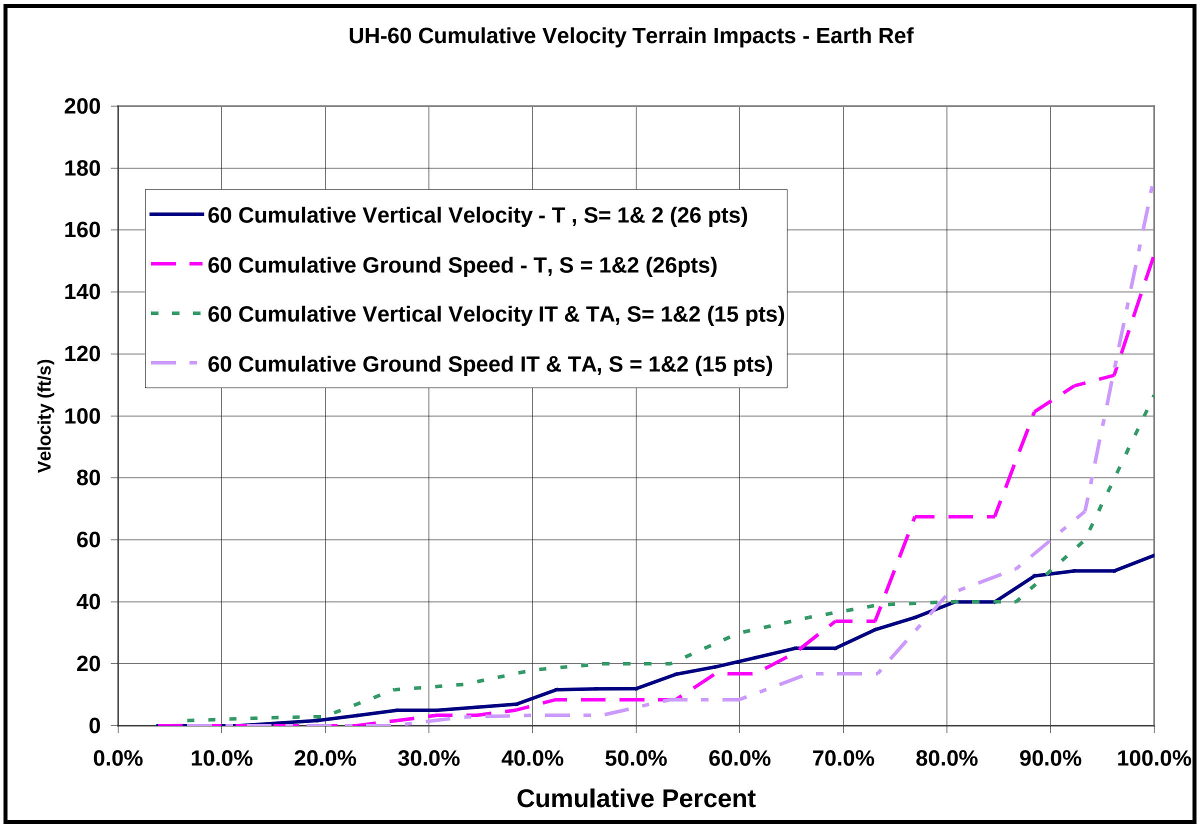

Figure 16 – UH-60 Terrain Impact Cumulative Velocities in the Earth Reference Frame (ERF)

This hypothesis was tested for the velocity populations of individual aircraft by comparing the medians and means of the five velocities studied in this report. The detailed results of this analysis are presented in Appendix B. The tables in the appendix present the medians and means for each velocity and the values for the statistical test parameters. To summarize these results, many aircraft types exhibit differences between the mean and/or median velocities of the T and IT&TA crashes which are of practical significance. That is, they differ enough to affect the amount of kinetic energy that must be absorbed in the crash. However, very few of the velocities could be confirmed to differ statistically. The populations showing statistically significant differences for one parameter are: the lateral velocity means for the AH-64 and OH-58AC, the lateral velocity medians for the OH-58D, the vertical velocity means for the OH-58AC, and the ground speed for the OH-58D. The vertical speed for the UH-1 differed with statistical significance for both parameters.

In many cases, the calculated means or medians differ by an amount that has practical importance. However, the variability in the data was such that the significance test failed. Thus, in most cases, the hypothesis that an impact with an obstacle prior to the terrain impact influences the terrain crash velocity is not confirmed statistically.

3.2.5 – Velocity Scatter Plots

Velocity scatter plots are a tool for visualizing two of the three component velocities of a crash. Each crash is represented by a point plotted using the two velocity values for those axes. Thus, each crash may

be plotted on three different axis pairs: vertical-longitudinal, vertical-lateral, and longitudinal-lateral. The crashes for each aircraft type have been divided into to two plots, one for the direct terrain (T) crashes and one for the post-obstacle crashes (IT&TA). Thus, each aircraft type has six plots. These plots are reproduced in Appendix C and an example is presented here in Figure 17. In each plot, the crash data points are coded by survivability (S=1, 2, or 3).

The estimated 95th-percentile survivability boundaries are added to these scatter plots. These boundaries are created by estimating the velocity of the 95th-percentile survivable crash in each direction along each principle axis. Thus, there is a 95th-percentile positive and a 95th-percentile negative velocity, if sufficient data are available. This 95th-percentile estimate is made by linear interpolation between the two velocity data points on either side of the 95th percentile for each half-axis. The curve joining each adjoining pair of half-axes is a quarter of the ellipse created from using the 95th-percentile velocity values as the intercepts in the standard formula for an ellipse. Thus, each quadrant is one fourth of an ellipse with a different formula. The dissimilarity of each quadrant can be clearly seen in the AH-64 data as presented in Figure 17. It should be emphasized that an ellipse is a simple choice for estimating the survivability boundary through each quadrant. One could view the use of an ellipse to make the boundary estimate as making the assumption that the response of the aircraft and occupants to the crash forces is isotropic. For the plots found in Appendix C, the absence of boundaries simply reflects insufficient data to determine a 95th-percentile value for a particular axis. In general, a minimum of ten data points were needed before estimating a 95th-percentile value.

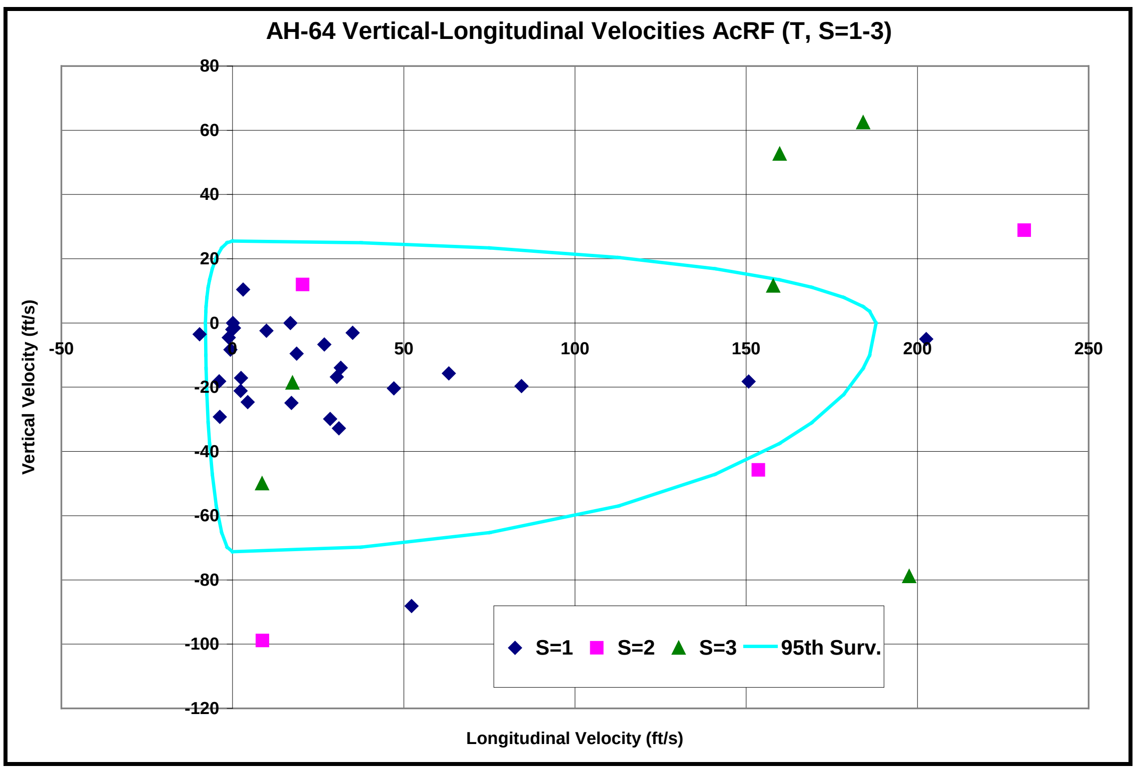

Figure 17 – AH-64 Direct to Terrain Velocity Scatter Plot

Separating the plots of the direct terrain crashes from those of the post-obstacle crashes has provided some insight into the distribution of the crash velocities. In previous work using scatter plots, the number of crashes with apparently upward and rearward velocities was somewhat surprising. Separating the plots by crash type reveals that many of these unexpected velocities occur in post-obstacle crashes. As an example, Figure 18 presents the vertical-longitudinal scatter plot for the AH-64 IT&TA crashes. It is apparent that there are quite a few crashes where the aircraft impacts on its roof and that some of these crashes have substantial velocities in the upward direction of the aircraft reference frame. Because the post-obstacle crashes represent roughly 30 percent of all crashes, the outcome and these crashes is an important consideration.

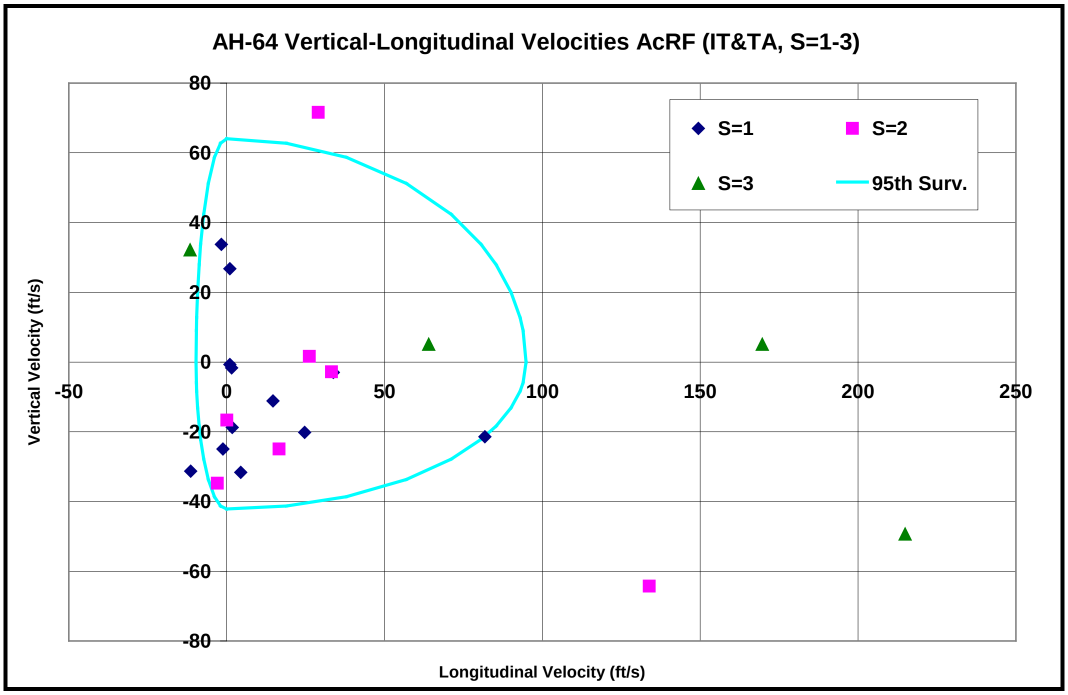

Figure 18 – AH-64 Post-obstacle Velocity Scatter Plot

3.2.6 – Inflight Velocities

For collisions with inflight obstacles, the database records the velocity at which the aircraft struck the obstacle. Figure 19 presents this plot for the UH-60. As might be expected, the horizontal velocities for these crashes are quite high, much higher than vertical velocities. Whereas the horizontal velocities for crashes into terrain only exceed 40 ft/s in the top few percent of crashes, the horizontal velocities for striking obstacles inflight exceeds 40 ft/s in fully 50 percent of the events. Although these data are for only 17 crashes, these 17 represent twenty percent of all the usable UH-60 crashes. Similar curves for the other aircraft types can be found in Appendix L.

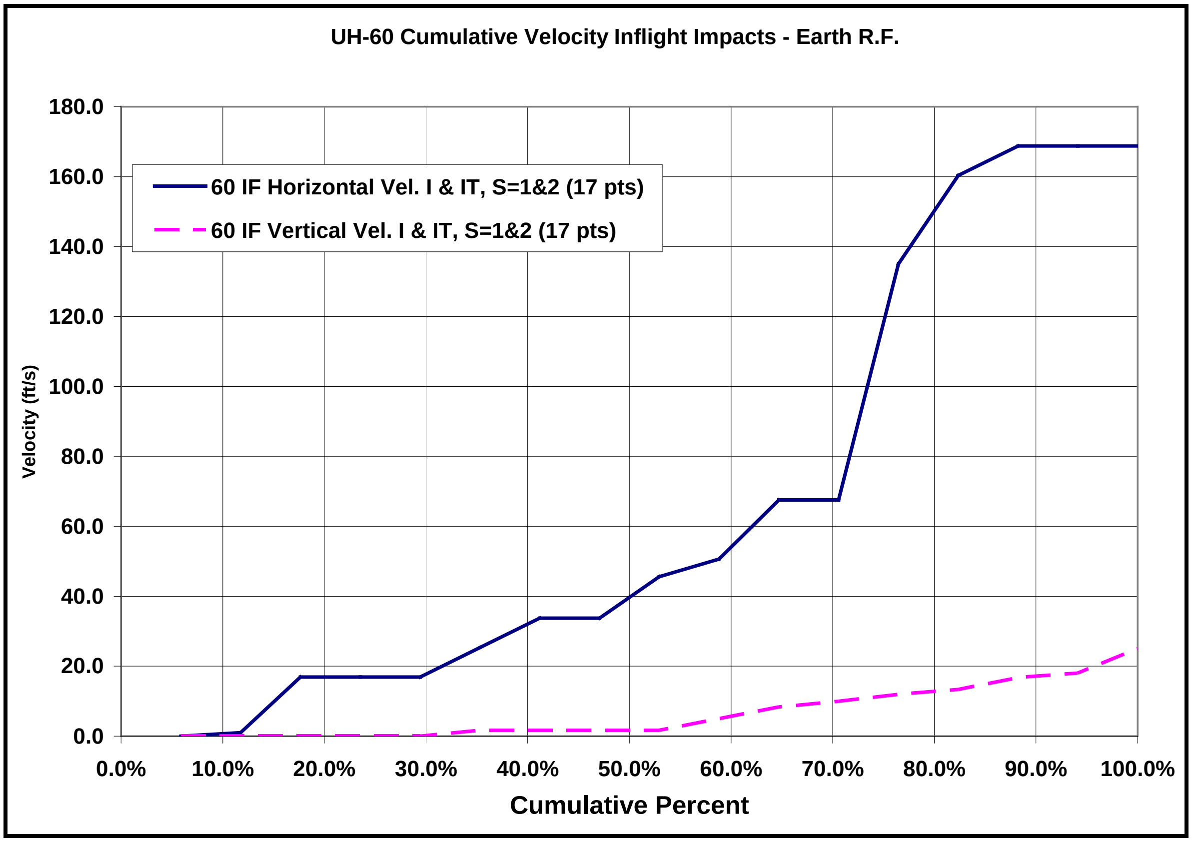

Figure 19 – UH-60 Inflight Impact Cumulative Velocities in the Earth Reference Frame

3.2.7 – Aircraft Attitude Angles at Impact with the Terrain

Five angles are recorded in the accident investigation report: the flight path angle, the terrain slope angle, and the three attitude angles of the aircraft. The flight path angle is combined with the terrain slope angle to calculate the impact angle. Figure 2 presents the relationships between the flight path angle, the slope angle and the impact angle. The flight path is always a positive angle, and the sign convention for the slope angle is that a slope rising in the flight direction is positive, a dropping slope is negative. Although rare, it is possible to crash down slope.

The verification of the crash kinematics data has already been discussed. The angle data were contained in the same spreadsheet files as were the velocity data. For the angle analysis to follow, the angle data from each aircraft were placed in a separate worksheet within a workbook. Within the aircraft-specific worksheet, data for each angle were divided into two groups, one for the terrain impacts (T) and one for the terrain impacts after obstacle impacts (IT & TA). Each data set included all crashes in the set that are survivable, partially survivable, and non-survivable crashes. A subset was created from each set that contained only the survivable and partially survivable crashes.

A worksheet was added to this workbook wherein the data for each angle from all of the aircraft were combined into two data sets for that angle. For example, one data set was created with the Flight Path angles for all terrain crashes (T) of all helicopter types combined. A similar data set was created for the Flight Path angles of crashes following obstacle impacts. These all aircraft data sets were used to create an all-aircraft reference curve.

A distribution or frequency histogram has been created for each of the five angles associated with the aircraft in a crash, the flight path angle, impact angle, and the three attitude angles, pitch roll, and yaw. The frequency distributions for these five angles have been plotted for each of the aircraft types. The angle distributions have traditionally been plotted as histograms—that is, vertical bar graphs with the number or percentage of crashes occurring within a certain angle range or "bin." Histograms of this type are difficult to read when attempting to compare two data sets. In this series of charts, a single point represents the percentage of crashes for which the angle fell within that increment. The data point is plotted at the center of the angle "bin." As a reference curve each plot also presents the frequency distribution for all the aircraft combined. These plots express the frequency as a percent of all crashes within the population. The plots for all aircraft types are presented in Appendix D.

It is reasonable to hypothesize that the distribution of impact and attitude angles for crashes after an obstacle impact would differ from those where the crash occurs directly into the terrain. Consequently, the following series of plots will present the angle distributions for the (T) crashes over the distributions for the (IT&TA) crashes.

Comparing the Flight Path angle distributions shown in Figure 20, a difference in the distributions between crashes occurring directly into terrain and those occurring following an obstacle strike is evident. Accidents occurring directly into terrain have a distinctly higher percentage occurring at low flight path angles. In contrast, crashes following an obstacle strike resulted more often in a nearly vertical descent. The impact angle differs from the flight path angle only by the slope angle. Since the slope angle was generally small, the comparison of the impact angles (see Figure 21) shows the same trend.

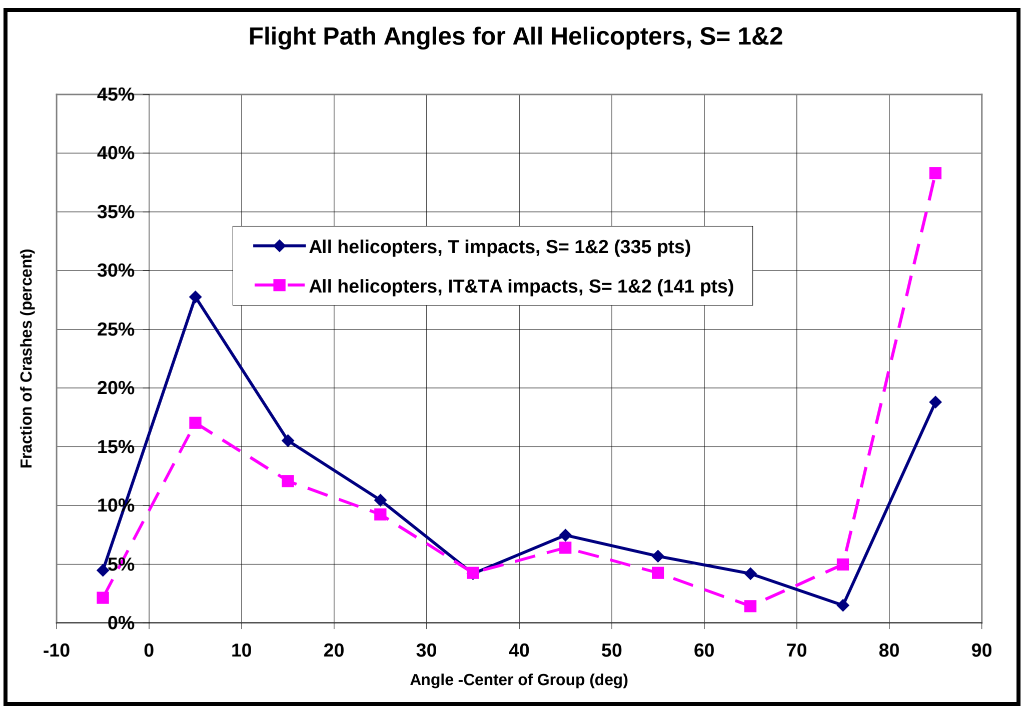

Figure 20 – Flight Path Angle Distribution Comparison between T and IT & TA

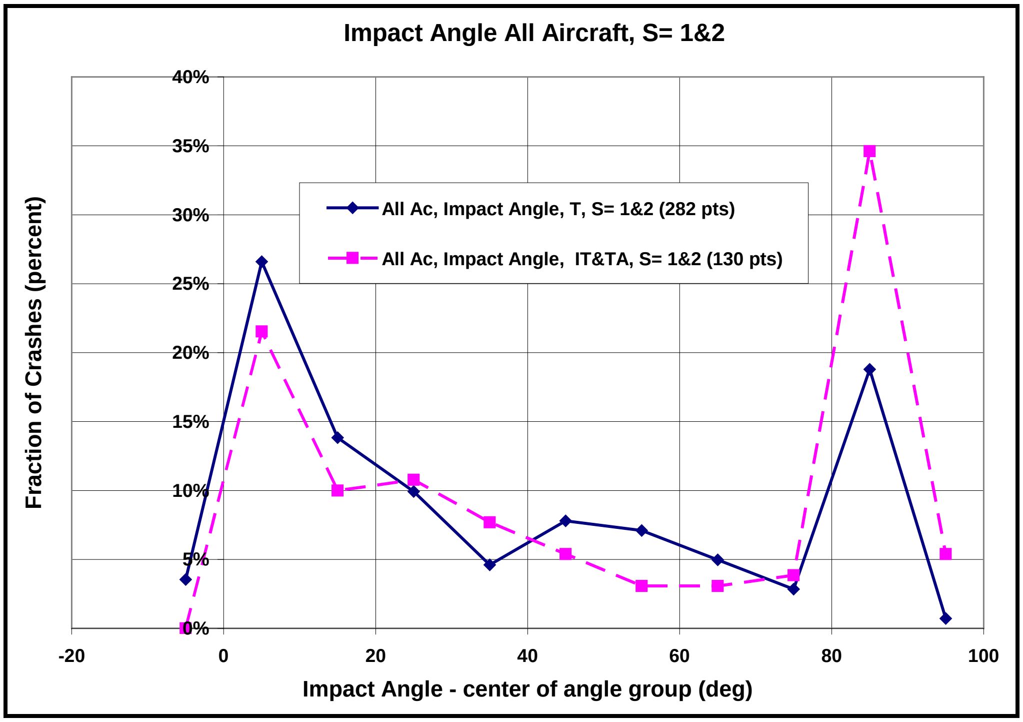

Figure 21 – Impact Angle Distribution Comparison between T and IT & TA

The differences in the attitude angles of the aircraft at impact between the two crash types were less than one might expect. The following three figures compare the Pitch, Yaw, and Roll angle distributions for the two types of crashes. The peak frequency in pitch angle (Figure 22) shows a small shift from nose up for the terrain crashes to nose down for crashes after obstacle strikes. This difference angle frequency may reflect the degree of control that the pilot would likely have in the two types of crashes. It was difficult to discern much difference between the two yaw curves (Figure 23), although fewer of the post-obstacle crashes appeared to occur near zero yaw and more occurred at high positive yaw angles. This small frequency difference may reflect the loss of directional control caused by contact between the tail rotor and the obstacle. However, if this hypothesis is valid, one might expect to see a broader distribution of crashes across all angles. Both of the roll curves peak at the nominal zero roll angle (Figure 24), but there is an unexplained cluster of crashes in the region of negative 100 degrees (rolled left-side down).

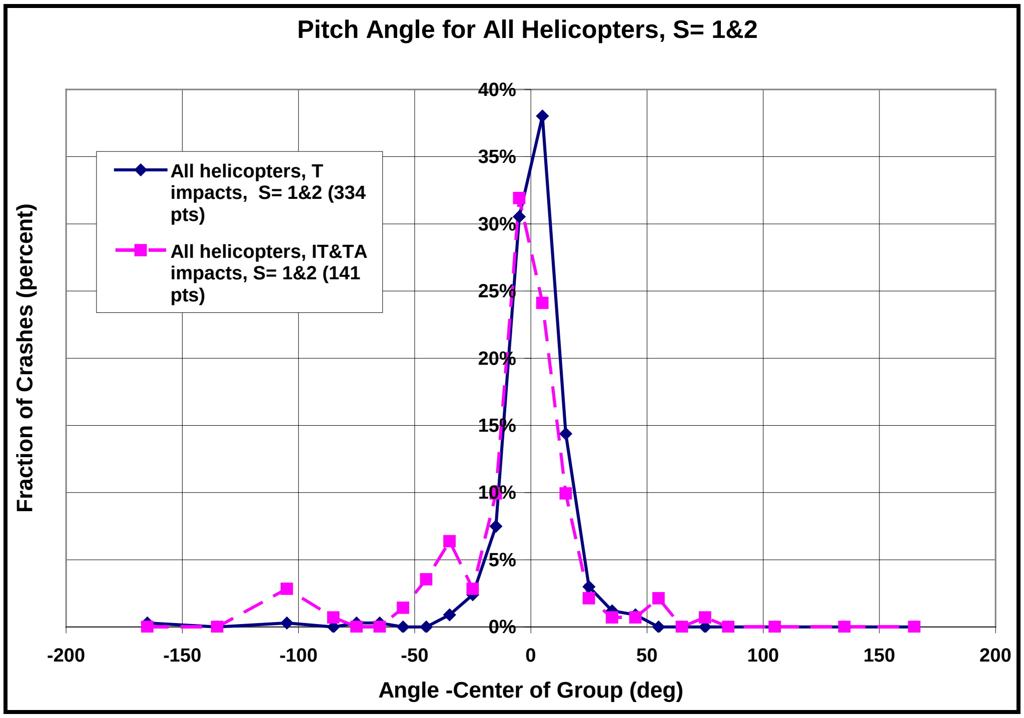

Figure 22 – Pitch Angle Distribution Comparison between T and IT & TA

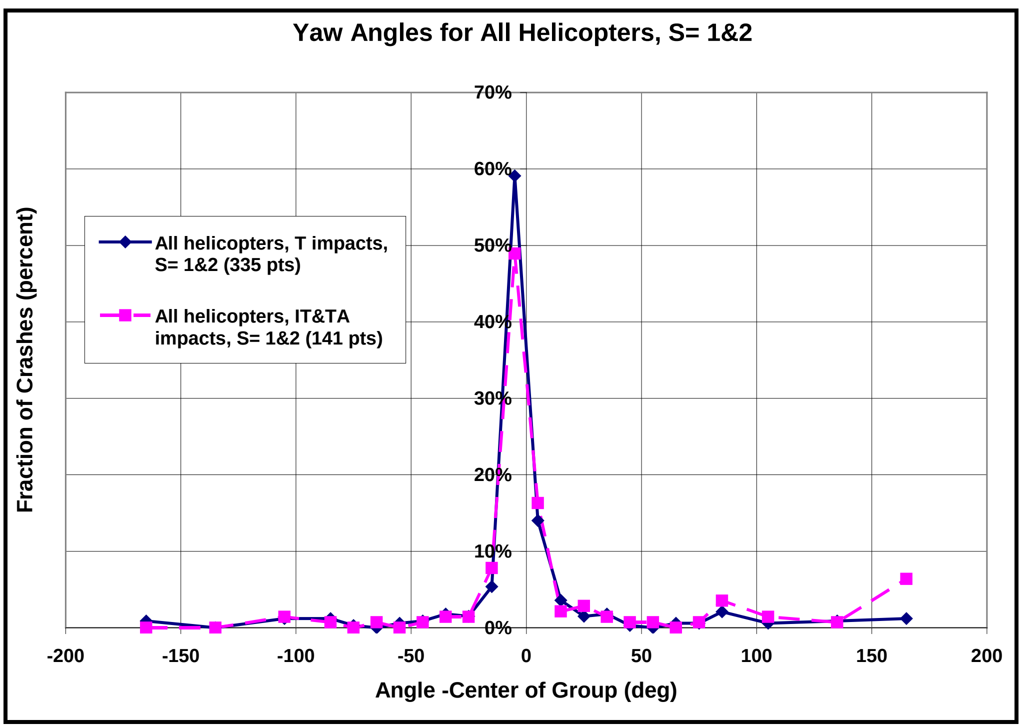

Figure 23 – Yaw Angle Distribution Comparison between T and IT & TA

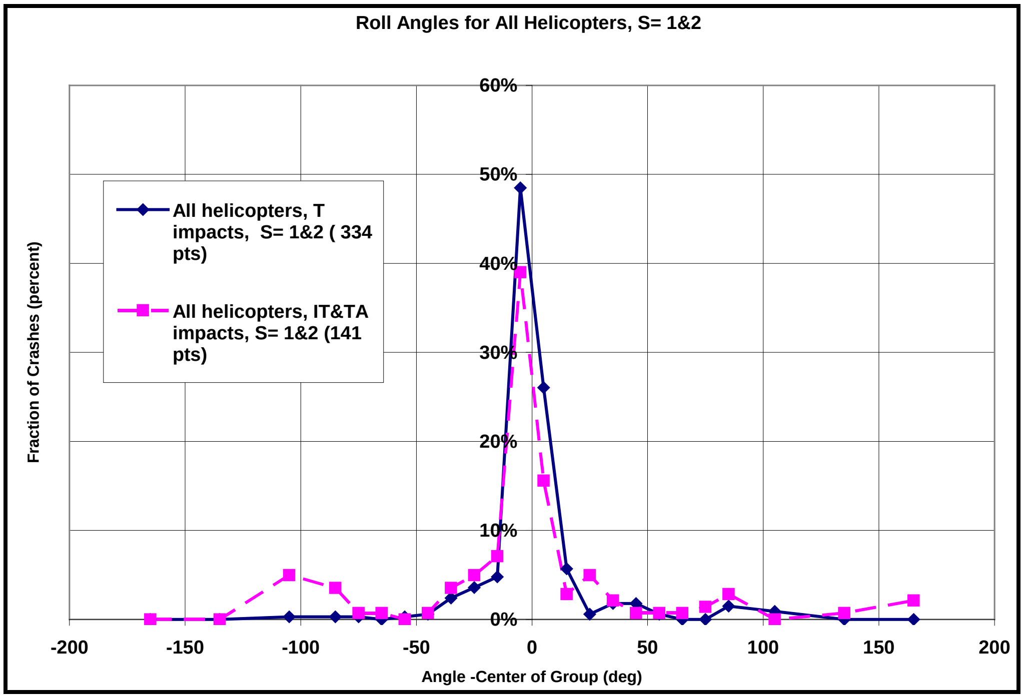

Figure 24 – Roll Angle Distribution Comparison between T and IT & TA

3.2.7.1 – Statistical Testing Attitude Angles for Crash Type Differences

The hypothesis that the crash angles are influenced by the events preceding the actual crash was formally tested statistically. Each angle for each aircraft was tested separately, as was each angle for the population of crashes for all aircraft. The medians were calculated for each angle. The Mann-Whitney Test was applied to the hypothesis that the median angles related to the T crashes differ from the median for the IT&TA crashes. The means were also tested using the Two-Sample T-Test. The results for each angle are discussed in the following three sections.

3.2.7.2 – Pitch Angle Crash Type Differences

For the attitude angle pitch, the OH-58AC and the population of all aircraft crashes have significant differences (Table 16). Both the means and the medians for the OH-58AC have positive values (nose up) for the terrain crashes, but they both have negative values (nose down) for the post-obstacle crashes. The variance values to the two populations also differ to a degree that is statistically significant. The difference in variance indicates that the variability in each population is different. The calculated values indicate that there is much greater variability in the angles for crashes following an obstacle strike than for those crashes where the aircraft impacts the ground directly.

Looking at the other aircraft, one sees similar trends for all three statistics. Both the median and mean values for each aircraft show a tendency for the pitch to be more positive in the T crashes than in the IT&TA crashes. With the sole exception of the AH-1, the variance is larger for the IT&TA crashes than for the T crashes. Although these differences were not statistically significant for the individual aircraft, the overall trend is confirmed by the fact that the population of all aircraft combined shows statistically significant differences for all three statistics. The medians, means, and variances all differ with statistical significance and the direction of the difference is consistent with the observed difference in the individual aircraft.

Table 16 – Pitch Angle Medians, Means, and Variances for Pitch Angles

Pitch	Medians		Means		Variances	
Aircraft	T	IT&TA	T	IT&TA	T	IT&TA
AH-1	3.00	-3.00	-1.26	-4.38	828	684
AH-64	2.50	0.00	0.344	-6.84	359	609
CH-47	8.00	Insuf.	8.41	Insuf.	296	Insuf.
OH-6	3.00	Insuf.	4.15	Insuf.	88.9	Insuf.
OH-58AC	3.00 *	-10.0	1.84	-17.2	87.8	906
OH-58D	7.00	10.5	6.67	8.40	196	155
UH-1	3.00	1.00	0.619	-2.40	526	1333
UH-60	1.00	-4.00	1.08	-6.21	118	271
All Aircraft	3.00	-2.50	1.71	-5.93	372	861

* Highlighted values were positive for a statistical test that the value for T population differed from the value for the IT&TA population.

3.2.7.3 – Roll Angle Crash Type Differences

For the attitude angle roll, the two types of crashes had similar mean and median roll angles. None of the aircraft nor the population of all aircraft crashes has a statistically significant difference for either the means or the medians (Table 17). However, comparing variance values between the two types of crashes, three aircraft types and the population of all aircraft crashes did differ to a degree that is statistically significant. The values indicate that there is much greater variability in the roll angles for crashes following an obstacle strike than for those crashes where the aircraft impacts the ground directly.

Looking at the individual aircraft, no trends are apparent in either the mean or the median. For three of the aircraft types, the variance is larger for the IT&TA crashes than for the T crashes and the difference is statistically significant. All of the aircraft types with data show the same trend in variance. Although these differences are not statistically significant for the individual aircraft, the overall trend is confirmed by the fact that the population of all aircraft combined is significant. The median is the more reliable indicator of the central value of a population because it is less affected by extreme values. The small values for the medians of the T and IT&TA populations indicate that the aircraft in either case are equally likely to crash rolled left as rolled right. The means are a mix of positive and negatives values for both the T and IT&TA crashes, indicating that there is no trend in the roll attitudes favoring positive or negative. This finding is confirmed by the means for the all aircraft population where the values for both the T crashes and the IT&TA crashes are close to zero.

Table 17 – Medians, Means, and Variances for Roll Angles

Roll	Medians		Means		Variances	
Aircraft	T	IT&TA	T	IT&TA	T	IT&TA
AH-1	-3.00	-3.00	-3.0	-13.7	167	1580
AH-64	3.00	-2.00	5.16	14.4	679	2743
CH-47	0.00	Insuf.	3.59	Insuf.	443	Insuf.
OH-6	-3.00	Insuf.	2.04	Insuf.	82.3	Insuf.
OH-58AC	0.00	-1.50	2.16	-6.90	795	1880
OH-58D	0.00	-1.50	-2.52	-3.70	262	3940
UH-1	0.00	0.00	1.74	-0.778	798	1510
UH-60	2.00	0.00	5.84	-2.71	812	3360
All Aircraft	0.00	-0.500	1.54	-0.563	557	2240

3.2.7.4 – Yaw

For the attitude angle yaw, just one of the aircraft displayed a significant difference between the means for the two crash types (Table 18). The variance values for one other aircraft type also displayed a significant difference. The population of all aircraft crashes displays differences for all three parameters that are statistically significant. The median values are for both the T crashes and the IT&TA crashes are zero. Although the statistical test indicates that this is a significant difference, the difference is of no practical consequence. The difference in the means indicates that following an obstacle strike the aircraft is likely to crash with the nose yawed further to the right (positive) than it would crashing directly into the terrain. Once again, the variance is greater for the post-obstacle crashes.

Looking at the individual aircraft, the values for all of the medians are within 3 degrees of zero. Suggesting that aircraft is equally likely to crash with the nose yawed right or left. This is true for both the T crashes and the IT&TA crashes, although three of the eight aircraft have a median value of three degrees to the left, a three-degree yaw is likely not significant to crashworthiness considerations. For the individual aircraft types, the means have a trend where the IT&TA crashes have larger positive angles than the T crashes. This trend is confirmed by the populations of all aircraft combined, where the mean for the IT&TA crashes is 15 degrees (right) compared to one-half degree for the T crashes and the difference is statistically significant. The higher positive value of the mean indicates that, although the aircraft may be equally likely to crash with yaw to the left or to the right, those crashes that exhibit extreme yaw values are more often to the right. Once again, the variances for the individual aircraft are higher for the IT&TA crashes than for the T. One of only two exceptions to this trend occurs in the yaw angle where the AH-64 has less variance in the IT&TA crashes than in the T crashes. The other exception was the AH-1 for pitch angle.

Table 18 – Medians, Means, and Variances for Yaw Angle

Yaw	Medians		Means		Variances	
Aircraft	T	IT&TA	T	IT&TA	T	IT&TA
AH-1	-3.00	0.00	3.44	16.7	679	4660
AH-64	0.00	0.00	-16.4	14.1	4260	1040
CH-47	-3.00	Insuf.	-2.71	Insuf.	106	Insuf.
OH-6	-3.00	Insuf.	-0.346	Insuf.	1650	Insuf.
OH-58AC	0.00	0.00	1.15	2.13	698	1025
OH-58D	0.00	0.00	9.74	33.4	681	5812
UH-1	0.00	0.00	3.30	14.9	2280	3870
UH-60	0.00	0.00	-3.68	30.0	1570	4930
All Aircraft	0.00	0.00	0.424	15.0	1550	3120

3.2.7.5 – Impact Angle

A similar statistical analysis was performed on the impact angles for each aircraft type and for the populations of all aircraft combined (Table 19). Once again general trends are apparent, but the statistical significance is sparse. The OH-58AC and the OH-58D had statistically significant differences between the medians and means of impact angles following obstacle strikes and those associated with terrain impacts. For both aircraft and for both parameters, the higher value is for the IT&TA crashes, indicating that the vertical speed is higher relative to the ground speed for these crashes. This trend is confirmed in the populations of all the aircraft grouped together. The IT&TA crashes exhibit higher impact angles than the T crashes indicating that vertical speed is higher relative to the ground speed for these crashes.

Table 19 – Medians, Means, and Variances for Impact Angles

Impact	Medians		Means		Variances	
Aircraft	T	IT&TA	T	IT&TA	T	IT&TA
AH-1	41.0	30.0	42.4	41.6	989	1130
AH-64	32.5	38.5	42.0	48.0	1250	1190
CH-47	28.0	Insuf.	36.4	Insuf.	1140	Insuf.
OH-6	26.0	Insuf.	33.1	Insuf.	834	Insuf.
OH-58AC	34.0	83.0	40.6	59.7	1060	1230
OH-58D	30.0	90.0	39.4	71.1	930	1410
UH-1	20.0	28.5	29.9	39.5	804	1120
UH-60	53.0	80.0	45.6	66.1	1280	740
All Aircraft	28.0	45.0	37.6	50.1	1000	1230

Since the flight path angle should be equal to the arc tangent of the vertical speed divided by the horizontal speed, these trends suggested by the impact angle should also be reflected in the velocities.

3.2.7.6 – Effect of Tail Rotor Height on Crash Attitude Angles

The hypothesis was that aircraft with tail rotors above the longitudinal axis through the center of gravity will suffer reduced roll and possibly pitch control, in addition to reduced yaw control when the tail rotor is compromised. Because the control system is biased to eliminate the roll moment caused by the tail rotor being above the center of gravity, the loss of tail rotor thrust would not only reduce yaw control, but it may cause the aircraft to roll. This roll would have to be neutralized by pilot response on the controls. The hypothesis was tested first on crash data for IT&TA type crashes because it was expected that this hypothetical effect would be stronger in this group.

To test this hypothesis, two groups of rotorcraft were created: Group A with a high tail rotor includes the AH-1, UH-1, AH-64, and UH-60, Group B with a neutral tail rotor includes the OH-6, OH-58AC and the OH-58D. The CH-47 uses two main rotors and no tail rotor and, consequently, was excluded from this analysis. Each group has a mix of main rotor system designs, so there is not a bias in that area. There may be a bias caused by aircraft missions; Group A comprises attack and utility helicopters, whereas Group b contains only observation helicopters.

Table 20 – Comparison of Attitude Angles by Tail Rotor Location

		Medians			Means			Variances	
Angle	**A**	**B**	**p**	**A**	**B**	**p**	**A**	**B**	**p**
Pitch	0.0	-5.0	0.23	-4.2	-10.4	0.25	889	820	0.40
Roll	0.0	-2.0	0.97	-0.89	-8.0	0.43	2030	2400	0.28
Yaw	0.0	0.0	0.62	17.2	10.3	0.46	3560	2240	0.43

The medians, means, and variances of each attitude angle were tested to see if these values for the two populations differed. Although the values of the measures differ (Table 20), the statistical test indicates that the differences are not significant. For the pitch attitude, the medians indicate that Group B, neutral tail rotor position, tends to crash more often nose down; this trend is confirmed by the mean value also being more negative for Group B. The variability in the pitch angle is nearly equal for the two groups. Greater yaw angles were anticipated in Group B where the tail rotor is lower and, consequently, more vulnerable to interference from below. However, the medians indicate no difference and the means actually indicate that Group A, the high tail rotor group, experiences greater deviations toward positive yaw. The variances also show greater variability in the Group A yaw angles. The roll angle is the crux of the hypothesis, and here the median shows a tendency for low tail rotor group to be rolled slightly more to the left at impact than the high tail rotor group. This trend is confirmed by a more negative mean value for Group B than for Group A. However, the differences are not statistically significant. The variance indicates that the high tail rotor group has greater variability in the roll attitude. However, this difference is also not statistically significant.

Because no significant effect was found in the IT&TA data set, the T data set was not tested.

The conclusion is that the vertical position of the tail rotor does not appear to affect the crash attitude angles for aircraft involved in crashes following inflight obstacle strikes.

3.3 – Flight Data Query

The information about the flight preceding the crash was extracted in two queries for each aircraft type: one extracted data associated with inflight impacts and one extracted data associated with terrain impacts. The data fields extracted in these two queries are listed in Table 21, together with the location of the data in the US Army investigation form.

Table 21 – Tables and Fields in Flight Data Query

Table	Field	Location on Investigation Form	Comment
AIRCRAFT_INFORMATION	CASE_NUMBER		Key Identifier
AIRCRAFT_INFORMATION	MTDS	2397-1-blk 8	A/c type
AIRCRAFT_INFORMATION	AIRCRAFT_NUMBER		# in mishap
AIRCRAFT_INFORMATION	OPERATION_TYPE	2397-1-blk 18b	
AIRCRAFT_INFORMATION	OPERATION_TYPE_DESC	2397-1-blk 18b	
AIRCRAFT_INFORMATION	MISSION_1	2397-1-blk 18a	
AIRCRAFT_INFORMATION	MISSION_1_DESC		
AIRCRAFT_INFORMATION	MISSION_2	2397-1-blk 18a	
AIRCRAFT_INFORMATION	MISSION_2_DESC		
AIRCRAFT_INFORMATION	MISSION_3	2397-1-blk 18a	
AIRCRAFT_INFORMATION	MISSION_3_DESC		
FLIGHT_DATA_INFORMATION	AIRCRAFT NUMBER		
FLIGHT_DATA_INFORMATION	AIRCRAFT_WEIGHT	2397-1-blk 21 (abc)	(lb)
FLIGHT_DATA_INFORMATION	OVERGROSS	2397-1-blk 21 (abc)	Y / N
FLIGHT_DATA_INFORMATION	PHASE_1	2397-1-blk 21 (abc)	
FLIGHT_DATA_INFORMATION	PHASE_1_DESC	2397-1-blk 21 (abc)	
FLIGHT_DATA_INFORMATION	PHASE_2	2397-1-blk 21 (abc)	
FLIGHT_DATA_INFORMATION	PHASE_2_DESC	2397-1-blk 21 (abc)	
FLIGHT_DATA_INFORMATION	PHASE_3	2397-1-blk 21 (abc)	
FLIGHT_DATA_INFORMATION	PHASE_3_DESC	2397-1-blk 21 (abc)	
FLIGHT_DATA_INFORMATION	AGL_ALTITUDE	2397-1-blk 21 (abc)	(ft)
FLIGHT_DATA_INFORMATION	MSL_ALTITUDE	2397-1-blk 21 (abc)	(ft)

Each query created a matrix of information. The results of the queries were exported from the MS Access database software to MS Excel spreadsheet software for consolidation. The fields associated with Block 21 on page 1 of the form, aircraft weight, phase, AGL altitude, and MSL altitude each had space provided for three responses. Thus, the queries extracted up to three records for each aircraft in each crash. In the reporting form, the three spaces are labeled as follows: a. Planned Data, b. When Emergency Occurred, and c. Accident or Termination. After the data were exported to a spreadsheet file, the data were rearranged to consolidate results for each crash into a single record associated with each

aircraft. Thus, in a mid-air collision, there would be two records, one for each aircraft. In the assigning of the masked case numbers, each aircraft received a separate case number rather than the event carrying the case number as in the database. In the spreadsheet created with the flight data query, more columns were added to contain the a., b., and c. values for the fields with multiple entries. Thus, in the worksheets, there is only one record associated with each crash aircraft. As obtained in the data table from the query, the individual values are not identified as to whether they correspond to the a., b., or c. line of Block 21. The Combat Readiness Center technical support personnel stated that data with the same record extracted by the query would be from the same line on the form. After placing the extracted records in the spreadsheet file, the records were sorted by diminishing aircraft weight and diminishing MSL altitude. This sorting strategy was intended to place the three records in the proper a.-b.-c. order. This sorting was done prior to consolidating the three records into a single record.

The database was generally well populated in these data fields, except MISSION and ALTITUDE_AGL. For each aircraft, the number of crashes with data in these fields was nearly equal to the number of usable crashes. Where the number of data records exceeded the number of crashes (for example, the UH-1), mid-air collisions involving two aircraft resulted in multiple records for that crash.

Table 22 – Number of Crashes with Flight Data Information

Aircraft	Usable Terrain Crashes [Code = *T*] (# of usable crashes)	Usable Inflight Crashes [Code IT & TA] (# of usable crashes)	Flight Data Mishaps with Output [Code = T] (# with data)	Flight Data Crashes with Output [Code = IT&TA] (# with data)
AH-1	68	26	65	26
AH-64	42	24	42	24
CH-47	21	3	21	3
OH-6	29	5	29	3
OH-58AC	*81*	*40*	*81*	*41*
OH-58D	*33*	*13*	*33*	*12*
OH-58 (Sum)	114	53	114	53
UH-1	103	51	104	52
UH-60	39	26	39	25
C-23	2	0	2	0

3.3.1 – Phase of Operation

The information relating to the phase of operation prior to and at the end of the accident sequence is recorded on page 1 of DA FORM 2397 in block 21 Flight Data. Descriptors for the phase of operation are recorded at three segments in the accident sequence: planned, when the emergency occurs, and accident or termination. For the "planned" phase, the guidelines[9] instruct the investigator to enter the

[9] DA Form 2397-R July 94, *Technical Report of U.S. Army Aircraft Accident.*

flight phase that was intended during preflight planning for that segment of the mission profile in which the emergency occurred. For the "emergency" segment, the guidelines instruct that the investigator report the phase "at the time of the emergency." For the "accident or termination, 'the descriptors applicable' at the time when the major impact/accident occurred or accident sequence stops" are to be recorded. In each of the three segments, up to three descriptors can be recorded.

The data from queries of the database files were recorded in spreadsheet files by aircraft. Since each segment of the crash sequence was allowed three phase descriptors, each crash record contained nine cells for phase descriptors. The number of times that each descriptor was recorded was counted up for each aircraft. Of the available descriptors, 24 descriptors appeared at least once in all of the aircraft considered in this study (Table 23). The data in Table 23 are for all aircraft in the study combined and describe the crashes directly into terrain (T).

Detailed information relating to Phase of Operation can be found in Appendix E. The number of times that each descriptor was reported in each of the mission segments is reported. The counts are broken out by aircraft type and by crash type (T or IT&TA). The appendix contains a brief explanation of the tables.

For the convenience of the reader, the definitions provided in the instructions for some of the phases follow:

- Crash: crew has no control over the aircraft attitude
- Contour: varying altitude, while maintaining constant height above the contour of the earth's surface/obstacles
- NOE: varying airspeed and altitude, using the earth's contour/foliage for concealment
- Low Level: constant airspeed and altitude below 500 ft AGL
- Descent: precedes Approach precedes Landing
- Termination with Power: planned/attempted termination of an autorotation to hover

Initially the descriptors were sorted according to the total number of times that each appeared and as a percentage of all the phase descriptors recorded. This view of the data is reflected on the right side of Table 23.

Table 23 – All Aircraft Numbers of Operational Phases for Terrain Impacts (T) S=all

	Planned Phase	Phase at Emergency	Phase at Accident Termination	Total		
Crashes				413		
Total Possible Descriptors	1239	1239	1239			
Cells: Blank	1179	810	736			
Cells with Data	60	429	503	992		
	Planned Phase	**Phase at Emergency**	**Phase at Accident Termination**	**Total**	**% of All Phases Recorded**	**Rank**
Landing Aircraft	4	59	205	268	27.0%	1
Emergency Autorotation	2	11	103	116	11.7%	2
Cruise	17	80	8	105	10.6%	3
Low Level	11	41	15	67	6.8%	4
Training Auto	2	29	27	58	5.8%	5
Takeoff	8	33	13	54	5.4%	6
Approach	4	32	10	46	4.6%	7
Descent	3	16	26	45	4.5%	8
Hover IGE	2	25	14	41	4.1%	9
Crash	0	0	40	40	4.0%	10
Turning	2	21	15	38	3.8%	11
Hover OGE	0	22	2	24	2.4%	12
Climb at Take-off	0	13	4	17	1.7%	13
Combat Maneuver	1	9	2	12	1.2%	14
Formation	3	7	1	11	1.1%	15
Go around/ TALS abort	0	8	3	11	1.1%	16
Contour	1	4	4	9	0.9%	17
NOE	0	5	1	6	0.6%	18
Deceleration	0	3	3	6	0.6%	19
Aerobatics	0	2	3	5	0.5%	20
Static Engine Run.	0	3	2	5	0.5%	21
Termination with Power	0	4	1	5	0.5%	22
Taxi	0	1	1	2	0.2%	23
Power Recovery	0	1	0	1	0.1%	24
Total Data	**60**	**429**	**503**	**992**	**100.0%**	

For the purposes of understanding the events preceding a crash, looking at the descriptor frequencies relative to the number of crashes is more informative than calculating the frequencies relative to the total number of phase descriptors reported. The operational phase data were tabulated as percentage frequencies of the number of crashes (Table 24). Further, since the information is recorded for different segments of the crash sequence, the relative frequencies of each phase can be viewed with respect to the chronology of the crash sequence.

Very few descriptors were reported for the "Planned" segment of the crashes; only 60 descriptors were reported for the 413 crashes. As might be expected the two most frequently reported descriptors are Cruise and Low Level. With so few reported descriptors, the information in this segment will contribute little information. Consequently, the analysis concentrates on the latter two segments: "At Time of Emergency" and "At Accident Termination."

The frequency at which various descriptors occur in these last to two segments was tabulated (Table 24). More descriptors (429) are reported for the segment entitled "At Time of Emergency" than were report for the "Planned" segment. These 429 descriptors represent an average of slightly more than one descriptor per crash. As the emergency is recognized, the most frequently reported phase is Cruise (19.4 percent), followed by Landing (14.3 percent), Low Level (9.9 percent), Takeoff (8 percent), and Training Autorotation (7 percent). Combining the Descent and Approach, which are the two segments preceding Landing, accounts for 11.6 percent. According to the reported descriptors, the landing sequence of Descent, Approach, and Landing is cited as the phase where the emergency develops in 26 percent of the crashes. The three phases associated with flying close to the terrain, NOE, Contour, and Low Level are the phases cited at the time of the emergency in 12.1 percent of the crashes. One of the two types of hover, IGE and OGE, are cited in 11.4 percent.

In the final segment of the accident sequence, the most common phase reported is the Landing phase (49.6 percent), followed by emergency autorotation (24.9 percent). Training autorotations are cited in 6.5 percent of the crashes. Interestingly, Crash is cited in only 9.7 percent of the events that this study has identified to be crashes. Part of this discrepancy may be attributed to the specific definition given for Crash in the instructions. The high percentage of events citing Landing and either type of autorotation indicates that the pilots remained at least partially in control of the aircraft, even though the outcome was measurable damage to the aircraft or injury to at least one occupant. This information suggests that designing helicopters to be crashworthy is justified on the basis that the pilot retains some ability to control the aircraft landing so as to maximize benefit from the crashworthy features of the aircraft.

Table 24 – All Aircraft Frequencies of Operational Phases for Terrain Impacts (T) S=all

	Cells with Data (992)		% of Crashes (413)		
	% of all Phases Recorded	Rank by Cells with Data	Total for All Segments	At Time of Emergency	At Accident Termination
Landing Aircraft	27.0%	1	64.9%	14.3%	49.6%
Emergency Autorotation	11.7%	2	28.1%	2.7%	24.9%
Cruise	10.6%	3	25.4%	19.4%	1.9%
Low Level	6.8%	4	16.2%	9.9%	3.6%
Training Autorotation	5.8%	5	14.0%	7.0%	6.5%
Takeoff	5.4%	6	13.1%	8.0%	3.1%
Approach	4.6%	7	11.1%	7.7%	2.4%
Descent	4.5%	8	10.9%	3.9%	6.3%
Hover IGE	4.1%	9	9.9%	6.1%	3.4%
Crash	4.0%	10	9.7%	0.0%	9.7%
Turning	3.8%	11	9.2%	5.1%	3.6%
Hover OGE	2.4%	12	5.8%	5.3%	0.5%
Climb at Take-off	1.7%	13	4.1%	3.1%	1.0%
Combat Maneuver	1.2%	14	2.9%	2.2%	0.5%
Formation	1.1%	15	2.7%	1.7%	0.2%
Go around/ TALS abort	1.1%	16	2.7%	1.9%	0.7%
Contour	0.9%	17	2.2%	1.0%	1.0%
NOE	0.6%	18	1.5%	1.2%	0.2%
Deceleration	0.6%	19	1.5%	0.7%	0.7%
Aerobatics	0.5%	20	1.2%	0.5%	0.7%
Stat Eng Run	0.5%	21	1.2%	0.7%	0.5%
Termination	0.5%	22	1.2%	1.0%	0.2%
Taxi	0.2%	23	0.5%	0.2%	0.2%
Power Recovery	0.1%	24	0.2%	0.2%	0.0%
Total Data	**100.0%**		**240.2%**	**103.9%**	**121.8%**

IT&TA Crashes

The data presented in Table 25 are the counts of the phases reported for the crashes following obstacles strikes (IT&TA). Although generally similar to trends seen for the terrain crashes, the specifics differ. Table 26 reports the frequencies of the phases relative to the number of crashes and thus, corresponds to Table 24 for the T events. As with the Terrain crashes, many of the same phases rank high in frequency,

but the frequencies in the IT&TA crashes are distributed over more phases. Very few phase descriptors are reported for the Planned segment of the crash sequence. The discussion will focus on the frequencies presented in Table 26 rather than the direct counts discussed in Table 25.

Table 25 – All Aircraft Numbers of Operational Phases for Post-Obstacle Impacts (IT&TA) S=all

Crashes	**186**					
Phase Descriptors	**Planned Segment**	**Emergency Segment**	**Accident Termination**	**Total**		
Total Possible Descriptors	558	558	558			
Cells: Blank	538	396	332			
Cells: With Data	20	162	226	408		

Phase Descriptors	**Planned Segment**	**Emergency Segment**	**Accident Termination**	**Total**	**% of All Phases Recorded**	**Rank**
Landing aircraft	1	11	55	67	16.4%	1
Low Level	4	29	32	65	15.9%	2
Cruise	3	27	11	41	10.0%	3
Turning	0	13	22	35	8.6%	4
Emergency Autorotation	0	1	27	28	6.9%	5
Hover OGE	3	16	7	26	6.4%	6
Crash	0	1	24	25	6.1%	7
Descent	0	6	14	20	4.9%	8
Approach	0	8	10	18	4.4%	9
Contour	4	8	5	17	4.2%	10
Hover IGE	0	9	4	13	3.2%	11
Formation	2	8	2	12	2.9%	12
Takeoff	0	6	3	9	2.2%	13
NOE	0	6	2	8	2.0%	14
Climb at Take-off	0	5	2	7	1.7%	15
Combat Maneuver	3	4	0	7	1.7%	16
Go around/ TALS abort	0	3	2	5	1.2%	17

Phase Descriptors	Planned Segment	Emergency Segment	Accident Termination	Total	% of All Phases Recorded	Rank
Training auto	0	1	1	2	0.5%	18
Deceleration	0	0	2	2	0.5%	19
Stat Eng Run	0	0	1	1	0.2%	20
Power Recovery	0	0	0	0	0.0%	21
Aerobatics	0	0	0	0	0.0%	22
Taxi	0	0	0	0	0.0%	23
Termination	0	0	0	0	0.0%	24
Total Phases Reported	**20**	**162**	**226**	**408**		

Low Level (15.6%) is reported as the most frequent phase at the time of the emergency. Low Level, NOE (3.2 %) and Contour (4.3%) are all reported at markedly higher frequencies than they were for the direct terrain crashes. NOE and Contour are each nearly four times more frequent in these post-obstacle crashes. Approach (4.3%), Descent (3.2%), and Landing combined are reported in only 13.4% of the crashes at the time of emergency compared to 25.9% for these combined in the same segment of the T crashes. Cruise is reported less often (14.5%) in the IT&TA crashes, but not dramatically less than for the T crashes (19.4%). The two types of hover are reported in this type of crash with frequencies similar to those for the T crashes: Hover OGE at 8.6% and Hover IGE at 4.8%.

In the Termination segment of the accident sequence, Landing was the predominant phase reported for the post-obstacle crashes. Although at 29.5%, Landing was not reported nearly as frequently as it was for the T accidents (49.6%). The second most frequently reported phase was Low Level (17.2%). Low Level and the two related phases NOE (1.1%) and Contour (2.7%) are all reported more frequently than they were for the final segment in the T crashes. Turning appears in 11.8% of the post-obstacle crashes compared with only 3.6% for the T crashes. This difference suggesting either that turning itself is somehow associated with obstacle strikes or that the aircraft are in the act of turning to avoid an obstacle as they strike an obstacle. The 14.5% frequency reported for Emergency Autorotations also suggests pilots remain in control even after obstacle strikes, despite the frequency being about 10 percentage points lower than for the T crashes.

Crash is reported as the phase in 12.9 percent of the IT&TA crashes compared to 9.7 percent of the T crashes. The difference suggests that more of the aircraft following obstacles strikes are considered to be completely out of the pilot's control; however, even this relatively larger frequency still seems to be an unexpectedly low frequency. Looking at the survivability data discussed in Section 3.1.4 and specifically comparing overall frequencies (Table 2 and Table 4), 14 percent of the terrain crashes were non-survivable and 8 percent were partially survivable, compared to 21 percent non-survivable and 21 percent partially survivable for the IT&TA crashes. Based on the marked lower survivability of crashes following obstacle strikes, we might expect to see a greater difference in the frequency of events identified as crashes.

Table 26 – All Aircraft Frequencies of Operational Phases for Post-Obstacle Impacts (IT&TA) S=all

	Cells with data (408)		% of Crashes (186)		
	% of all phases recorded	Rank by cells with data	% of Crashes for all segments	At Time of Emergency	At Accident Termination.
Landing aircraft	16.4%	1	36.0%	5.9%	29.6%
Low Level	15.9%	2	34.9%	15.6%	17.2%
Cruise	10.0%	3	22.0%	14.5%	5.9%
Turning	8.6%	4	18.8%	7.0%	11.8%
Emergency Autorotation	6.9%	5	15.1%	0.5%	14.5%
Hover OGE	6.4%	6	14.0%	8.6%	3.8%
Crash	6.1%	7	13.4%	0.5%	12.9%
Descent	4.9%	8	10.8%	3.2%	7.5%
Approach	4.4%	9	9.7%	4.3%	5.4%
Contour	4.2%	10	9.1%	4.3%	2.7%
Hover IGE	3.2%	11	7.0%	4.8%	2.2%
Formation	2.9%	12	6.5%	4.3%	1.1%
Takeoff	2.2%	13	4.8%	3.2%	1.6%
NOE	2.0%	14	4.3%	3.2%	1.1%
Climb at Take-off	1.7%	15	3.8%	2.7%	1.1%
Combat Maneuver	1.7%	16	3.8%	2.2%	0.0%
Go around/ TALS abort	1.2%	17	2.7%	1.6%	1.1%
Training Autorotation	0.5%	18	1.1%	0.5%	0.5%
Deceleration	0.5%	19	1.1%	0.0%	1.1%
Stat Eng Run	0.2%	20	0.5%	0.0%	0.5%
Power Recovery	0.0%	21	0.0%	0.0%	0.0%
Aerobatics	0.0%	22	0.0%	0.0%	0.0%
Taxi	0.0%	23	0.0%	0.0%	0.0%
Termination	0.0%	24	0.0%	0.0%	0.0%
Total			219.4%	87.1%	121.5%

3.3.2 – Altitude Data

The database contains information on two types of altitude: ALTITUDE_MSL and ALTITUDE_AGL. Each of the altitudes has fields for three values: planned, at time of emergency, and at termination.

The fields for the ALTITUDE_MSL are well populated. These data were used as an input variable in the regression analysis. Although the regression analysis identified the MSL altitude as statistically

significant in several models, the coefficients were generally very small; thus, the variable had minimal effect on the predicted values. The ALTITUDE_MSL data are not presented in this report.

The fields for the ALTITUDE_AGL were not well populated. Consequently, the AGL altitude was not used as an input variable in the regression analysis because using it would have markedly reduced the number of crashes included in the model. The absence of the AGL altitude from the model is most unfortunate, because altitude variable is a significant variable in any autorotation. The ALTITUDE_AGL data are not recorded in this report.

3.4 – Impact Effect Query

The query recovers data that quantifies the severity of the impact, motion of the aircraft following the impact, and damage to the aircraft. Because of the method used to place data into the database, the information on the damage to the aircraft consists of numerous data fields. In order to keep the queries and the data tables to a more manageable size, these data were extracted using three queries: IMP_EFFECT_FORCE&ROT, IMP_EFFECT_HULL_CRUSH, and IMP_EFFECT_DISPL_TORN. Each of these three queries was executed once for the direct terrain (T) impacts and again for the terrain impacts following obstacle impacts (IT & TA).

The FORCE&ROT query extracted the information on the direction and force of the impact in Gs and the and extent of any aircraft rotation that occurred following the impact (Table 27). The first few fields identify the crash and the aircraft, the following three fields quantify the impact severity in Gs. These values were estimated by the crash investigator and are provided as values along the major axes in the aircraft frame of reference. Following these fields are six fields quantifying the rotation of the aircraft after impact and the direction about each of the major aircraft axes.

Table 27 – Tables and Fields for IMP_EFFECT_FORCE&ROT Query

Table	Field	Source in Investigation Form	Comment
IMPACT_EFFECTS_INFORMATION	CASE_NUMBER	All pages	
IMPACT_EFFECTS_INFORMATION	AIRCRAFT_NUMBER	2397-1/ 25	
AIRCRAFT_INFORMATION	MTDS	2397-1/ 8a	
AIRCRAFT_INFORMATION	SURVIVABILITY	2397-1/ 11	
IMPACT_EFFECTS_INFORMATION	VERTICAL_G	2397-6/ 4a	(G)
IMPACT_EFFECTS_INFORMATION	VERTICAL_DIRECTION	2397-6 / 4a	D = +
IMPACT_EFFECTS_INFORMATION	LONGITUDINAL_G	2397-6/ 4b	(G)
IMPACT_EFFECTS_INFORMATION	LONGITUDINAL_DIRECTION	2397-6/ 4b	Fwd = +
IMPACT_EFFECTS_INFORMATION	LATERAL_G	2397-6/ 4c	(G)
IMPACT_EFFECTS_INFORMATION	LATERAL_DIRECTION	2397-6/ 4c	R = +
IMPACT_EFFECTS_INFORMATION	ROLL_DEGREE	2397-6/ 3b	(degr)
IMPACT_EFFECTS_INFORMATION	ROLL_DIRECTION	2397-6/ 3b	RW down = +
IMPACT_EFFECTS_INFORMATION	YAW_DEGREE	2397-6/ 3c	(degr)
IMPACT_EFFECTS_INFORMATION	YAW_DIRECTION	2397-6/ 3c	R = +
IMPACT_EFFECTS_INFORMATION	PITCH_DEGREE	2397-6/ 3d	(degr)
IMPACT_EFFECTS_INFORMATION	PITCH_DIRECTION	2397-6/ 3d	Up = +

The HULL_CRUSH query extracts the values from a series of fields that quantify the deformation of the airframe (Table 28). Damage to the roof is reported in three course increments: less than one foot, more than one foot and less than three feet, or more than three feet. In interpreting this data, it is inferred that no response implies no damage to that area (guidelines state that <3 in. of damage may be reported as no damage); so in effect, there are four possible levels of damage to the roof. The remainder of the regions are reported at only two levels of damage: less than 1 foot and greater than 1 foot. There are two fields for each of 22 areas of the fuselage: one field quantifies the deformation in the increments described above and the second states whether the deformation in that area contributed to the injury of an occupant. The last two fields in this query capture whether the landing gear penetrated the cabin.

Table 28 – Tables and Fields for IMP_EFFECT_HULL_CRUSH Query

Table	Field	Source in Investigation Form	Comment
IMPACT_EFFECTS_INFORMATION	CASE_NUMBER	All pages	
IMPACT_EFFECTS_INFORMATION	AIRCRAFT_NUMBER	2397-1/ 25	
AIRCRAFT_INFORMATION	MTDS	2397-1/ 8a	
AIRCRAFT_INFORMATION	SURVIVABILITY	2397-1/ 11	
IMPACT_EFFECTS_INFORMATION	ROOF_COCKPIT_ AMOUNT_DESC	2397-6/ 7a(1)	(G)
IMPACT_EFFECTS_INFORMATION	ROOF_COCKPIT_ CONTRIBUTED	2397-6/ 7a(5)	Y/N
IMPACT_EFFECTS_INFORMATION	ROOF_FORWARD_ AMOUNT_DESC	2397-6/ 7a(2)	
IMPACT_EFFECTS_INFORMATION	ROOF_FORWARD_ CONTRIBUTED	2397-6/ 7a(6)	Y/N
IMPACT_EFFECTS_INFORMATION	ROOF_MID_ AMOUNT_DESC	2397-6/ 7a(3)	
IMPACT_EFFECTS_INFORMATION	ROOF_MID_ CONTRIBUTED	2397-6/ 7a(7)	Y/N
IMPACT_EFFECTS_INFORMATION	ROOF_REAR_ AMOUNT_DESC	2397-6/ 7a(4)	
IMPACT_EFFECTS_INFORMATION	ROOF_REAR_ CONTRIBUTED	2397-6/ 7a(8)	Y/N
IMPACT_EFFECTS_INFORMATION	LEFT_COCKPIT_ AMOUNT_DESC	2397-6/7b(1)	
IMPACT_EFFECTS_INFORMATION	LEFT_COCKPIT_ CONTRIBUTED	2397-6/7b(5)	Y/N
IMPACT_EFFECTS_INFORMATION	LEFT_FORWARD_ AMOUNT_DESC	2397-6/7b(2)	
IMPACT_EFFECTS_INFORMATION	LEFT_FORWARD_ CONTRIBUTED	2397-6/7b(6)	Y/N
IMPACT_EFFECTS_INFORMATION	LEFT_MID_AMOUNT_ DESC	2397-6/7b(3)	
IMPACT_EFFECTS_INFORMATION	LEFT_MID_ CONTRIBUTED	2397-6/7b(7)	Y/N
IMPACT_EFFECTS_INFORMATION	LEFT_REAR_ AMOUNT_DESC	2397-6/7b(4)	
IMPACT_EFFECTS_INFORMATION	LEFT_REAR_ CONTRIBUTED	2397-6/7b(8)	Y/N
IMPACT_EFFECTS_INFORMATION	RIGHT_COCKPIT_ AMOUNT_DESC	2397-6/7c(1)	
IMPACT_EFFECTS_INFORMATION	RIGHT_COCKPIT_ CONTRIBUTED	2397-6/7c(5)	Y/N
IMPACT_EFFECTS_INFORMATION	RIGHT_FORWARD_ AMOUNT_DESC	2397-6/7c(2)	
IMPACT_EFFECTS_INFORMATION	RIGHT_FORWARD_ CONTRIBUTED	2397-6/7c(6)	Y/N
IMPACT_EFFECTS_INFORMATION	RIGHT_MID_ AMOUNT_DESC	2397-6/7c(3)	
IMPACT_EFFECTS_INFORMATION	RIGHT_MID_ CONTRIBUTED	2397-6/7c(7)	Y/N
IMPACT_EFFECTS_INFORMATION	RIGHT_REAR_ AMOUNT_DESC	2397-6/7c(4)	
IMPACT_EFFECTS_INFORMATION	RIGHT_REAR_ CONTRIBUTED	2397-6/7c(8)	Y/N

Table	Field	Source in Investigation Form	Comment
IMPACT_EFFECTS_INFORMATION	NOSE_COCKPIT_ AMOUNT_DESC	2397-6/7d(1)	
IMPACT_EFFECTS_INFORMATION	NOSE_COCKPIT_ CONTRIBUTED	2397-6/7d(5)	Y/N
IMPACT_EFFECTS_INFORMATION	NOSE_FORWARD_ AMOUNT_DESC	2397-6/7d(2)	
IMPACT_EFFECTS_INFORMATION	NOSE_FORWARD_ CONTRIBUTED	2397-6/7d(6)	Y/N
IMPACT_EFFECTS_INFORMATION	FLOOR_COCKPIT_ AMOUNT_DESC	2397-6/7e(1)	
IMPACT_EFFECTS_INFORMATION	FLOOR_COCKPIT_ CONTRIBUTED	2397-6/7e(5)	Y/N
IMPACT_EFFECTS_INFORMATION	FLOOR_FORWARD_ AMOUNT_DESC	2397-6/7e(2)	
IMPACT_EFFECTS_INFORMATION	FLOOR_FORWARD_ CONTRIBUTED	2397-6/7e(6)	Y/N
IMPACT_EFFECTS_INFORMATION	FLOOR_MID_ AMOUNT_DESC	2397-6/7e(3)	
IMPACT_EFFECTS_INFORMATION	FLOOR_MID_ CONTRIBUTED	2397-6/7e(7)	Y/N
IMPACT_EFFECTS_INFORMATION	FLOOR_REAR_ AMOUNT_DESC	2397-6/7e(4)	
IMPACT_EFFECTS_INFORMATION	FLOOR_REAR_ CONTRIBUTED	2397-6/7e(8)	Y/N
IMPACT_EFFECTS_INFORMATION	SEAT_COCKPIT_ AMOUNT_DESC	2397-6/7f(1)	
IMPACT_EFFECTS_INFORMATION	SEAT_COCKPIT_ CONTRIBUTED	2397-6/7f(5)	Y/N
IMPACT_EFFECTS_INFORMATION	SEAT_FORWARD_ AMOUNT_DESC	2397-6/7f(2)	
IMPACT_EFFECTS_INFORMATION	SEAT_FORWARD_ CONTRIBUTED	2397-6/7f(6)	Y/N
IMPACT_EFFECTS_INFORMATION	SEAT_MID_ AMOUNT_DESC	2397-6/7f(3)	
IMPACT_EFFECTS_INFORMATION	SEAT_MID_ CONTRIBUTED	2397-6/7f(7)	Y/N
IMPACT_EFFECTS_INFORMATION	SEAT_REAR_ AMOUNT_DESC	2397-6/7f(4)	
IMPACT_EFFECTS_INFORMATION	SEAT_REAR_ CONTRIBUTED	2397-6/7f(8)	Y/N
IMPACT_EFFECTS_INFORMATION	LANDING_GEAR_CABIN	2397-6/8e(4)	Y/N
IMPACT_EFFECTS_INFORMATION	LANDING_GEAR_ LOCATION	2397-6/8e	Position

The DISPL_TORN query extracts information about the movement of the high mass items as a result of the impact (Table 29). The items covered are the main transmission, the rear transmission, the main rotor, the tail rotor, and the landing gear. Each item has a field labeled “displaced” and a field labeled “torn free.” Each of these fields is either a “Yes” or “No” response. The last field in this query describes the position of the displaced or torn free landing gear. For this latter field, the coded version rather than the description version of the field was included in the query. Thus, a conversion table is required for this field (Table 30).

Table 29 – Tables and Fields for IMP_EFFECT_DISPL_TORN Query

Table	Field	Source in Investigation Form	Comment
IMPACT_EFFECTS_INFORMATION	CASE_NUMBER	All pages	
IMPACT_EFFECTS_INFORMATION	AIRCRAFT_NUMBER	2397-1/ 25	
AIRCRAFT_INFORMATION	MTDS	2397-1/ 8a	
AIRCRAFT_INFORMATION	SURVIVABILITY	2397-1/ 11	
IMPACT_EFFECTS_INFORMATION	TRANSMISSION_MAIN_ DISPLACED	2397-6/8a(1)	Y/N
IMPACT_EFFECTS_INFORMATION	TRANSMISSION_MAIN_ TORNFREE	2397-6/8a(2)	Y/N
IMPACT_EFFECTS_INFORMATION	TRANSMISSION_REAR_ DISPLACED	2397-6/8b(1)	Y/N
IMPACT_EFFECTS_INFORMATION	TRANSMISSION_REAR_ TORNFREE	2397-6/8b(1)	Y/N
IMPACT_EFFECTS_INFORMATION	ROTOR_MAIN_ DISPLACED	2397-6/8c(1)	Y/N
IMPACT_EFFECTS_INFORMATION	ROTOR_MAIN_ TORNFREE	2397-6/8c(2)	Y/N
IMPACT_EFFECTS_INFORMATION	ROTOR_TAIL_ DISPLACED	2397-6/8d(1)	Y/N
IMPACT_EFFECTS_INFORMATION	ROTOR_TAIL_ TORNFREE	2397-6/8d(2)	Y/N
IMPACT_EFFECTS_INFORMATION	LANDING_GEAR_ DISPLACED	2397-6/8e(1)	Y/N
IMPACT_EFFECTS_INFORMATION	LANDING_GEAR_ TORNFREE	2397-6/8e(2)	Y/N
IMPACT_EFFECTS_INFORMATION	LANDING_GEAR_ LOCATION	2397-6/8e	Coded

Table 30 – Landing Gear Location Codes and Descriptions

(Conversion Table for Table 29 Query Output)

Location Code	Location Description
1	LEFT FRONT (LT FRT)
2	CENTER FRONT (CTR FRT)
3	RIGHT FRONT (RT FRT)
4	LEFT REAR (LT RER)
5	CENTER REAR (CTR RER)
6	RIGHT REAR (RT RER)
7	FORWARD (ALL)
8	AFT (ALL)
9	ALL

3.4.1 – Impact Severity and Post-impact Rotation

The impact severity is recorded in the database as the estimated impact force in Gs along each of the aircraft's three major axes. The information is gathered in the report form and recorded in the database as a magnitude and a direction for each axis. The up/down, left/right, and forward/aft have been converted to algebraic values with up, right and forward being positive. The values were extracted using queries that separated the data into two crash sets for each aircraft, the direct impacts to terrain (T) and the impacts following inflight obstacle strikes (IT & TA). It was anticipated that the data in the two groups would be markedly different and in some cases that has proven to be true. A related set of information was extracted with this same query—that is, the angle through which the aircraft rotated following the initial impact. This information is indicative of the violence that the occupants were subjected to during the entire event.

3.4.1.1 – Impact Severity

The data for each aircraft type are presented in two groups, one group for each crash type. The average and the standard deviation were calculated for data in each crash type and on each axis. The averages include both positive and negative values. The values of the standard deviations are generally larger than the average values suggesting that simply considering average values will render an incomplete understanding of the data. Table 31 presents the data for the T type crashes and Figure 32 presents the data for the IT&TA crashes. The column headed "number of crashes with data" indicates the number of crashes that had data for at least one axis, several crashes had incomplete data. Because some of the average values were so close to zero, a histogram was created to look at the distribution of values.

Table 31 – Summary of Impact Severity for T Crashes

Aircraft T Crashes	# of Crashes with Data	Z Decel. (G) Avg. Stdev.	X Decel. (G) Avg. Stdev.	Y Decel. (G) Avg. Stdev.
UH-60	33	-5.7	0.2	0.8
		28.4	47.2	26.7
UH-1	45	-9	-4.1	-4.7
		31.8	33.7	19.5
OH-58AC	41	-3.4	2.6	-12.2
		25.1	31.2	33.2
OH-58D	31	-1.4	1.2	-3.8
		9.3	6	28.1
OH-6	2	-11	2	N.A.
		12.7	N.A.	N.A.
CH-47	11	-25	1.7	-7
		60.6	36	16.9
AH-64	36	-10	-5	10
		30.7	36.1	31.4
AH-1	14	-8.5	9.2	4.1
		28.4	30	13.9

Table 32 – Summary of the Impact Severity for IT&TA Crashes

Aircraft IT&TA Crashes	# of Crashes with Data	Z Decel. (G) Avg. Stdev.	X Decel. (G) Avg. Stdev.	Y Decel. (G) Avg. Stdev.
UH-60	24	-1.3	17.9	-4.9
		68	65.1	11.5
UH-1	26	-11.8	13.6	5
		42.4	20.9	25.3
OH-58AC	20	-4	-0.7	4.5
		19.9	50.5	26.5
OH-58D	12	-5.9	-2.3	2.1
		30.8	6.8	19.1
OH-6	1	No data	-90	No data
			N.A.	
Ch-47	2	12.5	65	-22
		7.8	N.A.	N.A.
AH-64	20	-6.7	20.7	-3.9
		24.8	44.8	23.3
AH-1	12	10	23.9	6.4
		44.9	31.1	35.3

The impact severity along each axis for the UH-60 is plotted as a histogram in Figure 25. In the vertical direction, the greatest frequency of events occurs near zero G and extends downward into the negative values corresponding to downward impacts. What is surprising in this plot is the frequency of positive impacts (i.e., the relatively large number of impacts reported as having an upward impact force). A similar trend is found in the IT&TA crashes. Counting up the positive and negative values yields that 20 crashes had negative or downward impact forces and 13 had upward or positive impact forces. The indication that 40 percent of the crashes directly into terrain occur inverted or with an upward impact direction does not seem consistent with other parameters. Performing a similar count of the signs associated with the vertical *velocity* in the aircraft reference frame finds that 75 percent (27/36) of the T crashes occur with downward velocity along the aircraft Z axis. A similar count for all of the UH-60 mishaps with calculated vertical velocity values found a similar fraction (76 percent) to be downward.

The following paragraph is a note on positive vertical velocities. A careful consideration of vertical velocity reveals that an aircraft can crash with a positive vertical velocity in the aircraft reference frame without crashing in an inverted attitude. One such scenario is a high-ground speed relative to the sink the rate, combined with a nose low attitude. In a case where the ground speed is three times the sink rate, the transition from a negative vertical velocity to a positive vertical velocity occurs as the nose drops through -18 degrees. Looking at the crashes with positive vertical velocities, one might expect to see two groups of crashes. One group with relatively low positive vertical velocities, these crashes would be of those described above with high ground speed, low vertical speed and nose down attitude. The second group

would be those where the aircraft actually did crash inverted. These events would be characterized by relatively high positive vertical velocities and extreme values in at least one of the attitude angles. In scanning through all of the UH-60 crashes (usable and unusable), one observes this general trend toward two distinct groups.

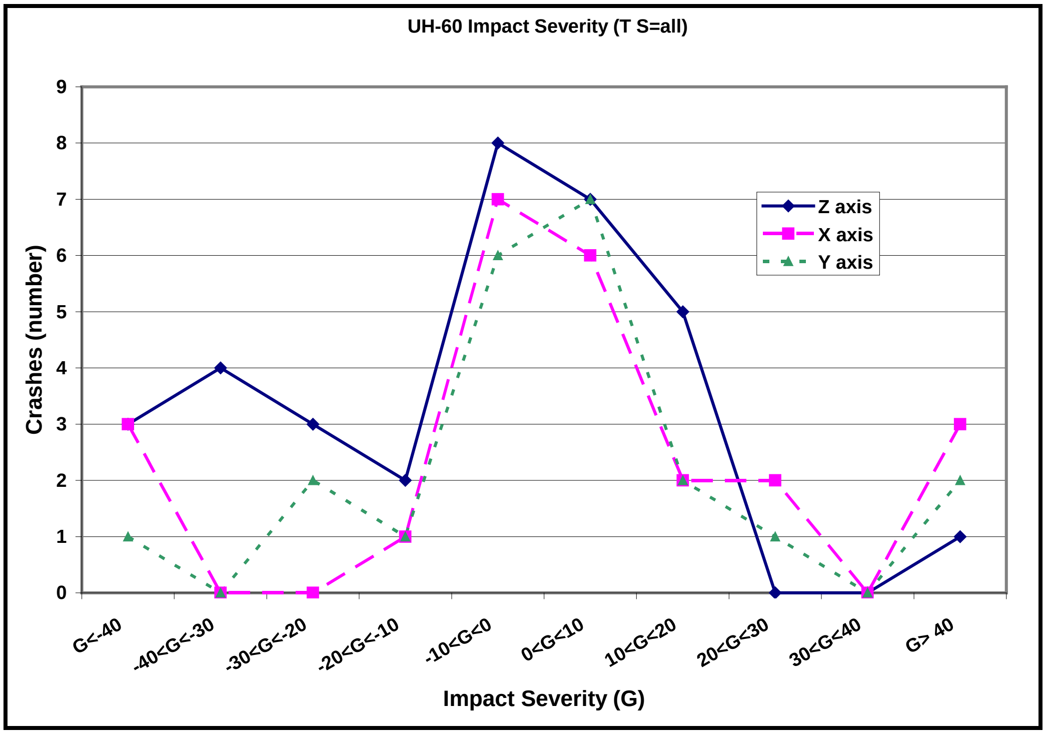

Figure 25 – UH-60 Vertical Impact Severity (T, S=all)

In order to identify where the inconsistency occurs, the author looked back to DA Pamphlet 385-40[3]. The accident report form[4] calls for the estimated magnitude of the impact force to be entered in Gs and for the direction to be entered by checking a box for either UP or DOWN. The pamphlet instructions do not clarify the meaning of up and down for the purposes of the impact force. The data from the form is recorded in the database in two fields, one for the magnitude and one for the direction, UP or DOWN. The spreadsheet converts UP to a plus magnitude and DOWN to a negative magnitude through an IF statement. The author concludes that there is inconsistency in recording the direction of the impact force. To verify this, the author looked at the crash kinematics data for the UH-60. This spreadsheet contains both the velocity data and the impact severity data. By comparing the sign for the vertical velocity in the aircraft reference frame and the direction of the impact force, more information could be gathered about the correlation between the two. One would expect that the two parameters will have like signs. Looking at just the T type crashes, 19 crashes had similar signs, but 14 had opposite signs. Checking the IT&TA crashes found a similarly poor correlation between signs; ten crashes had similar signs, but eleven had opposite signs. The author concludes that the magnitude of the impact severity may have some value for this study; however, any information extracted from the sign should not be used for decision making.

A new histogram was created to consider only the magnitude of the impact forces. The absolute value was taken of each impact force datum and a new histogram plot made to present the distribution of these values. For the vertical direction, a value of 15 G is of interest because this value is slightly higher than the stroking force for most energy absorbing seats. As Figure 26 reveals, there is a substantial fraction of crashes at severities well above the 15 G level.

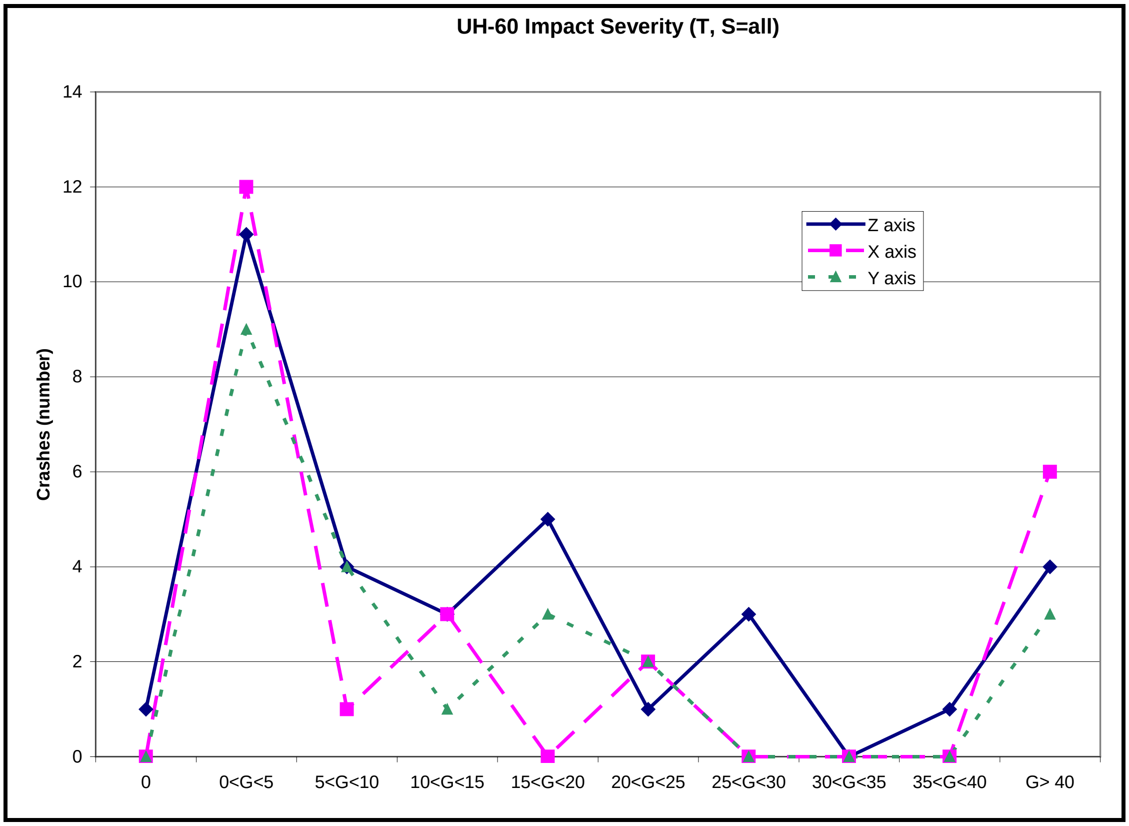

Figure 26 – UH-60 Impact Severity Absolute Value

The impact forces in the longitudinal direction are approximately 50 percent higher than those in the vertical direction (Table 33). Somewhat surprisingly, the average impact force in the lateral direction is nearly as great (85 percent) as the average impact force in the vertical direction for this aircraft.

Table 33 – UH-60 Impact Severity in Aircraft Reference Frame (T, S= all)

	Z axis Vertical (G)	X axis Longitudinal (G)	Y axis Lateral (G)
Average	18.6	27.2	15.9
Standard Deviation	21.9	38.1	21.3

Looking at the data for the UH-60 IT&TA crashes (Table 34) reveals a very different pattern of forces. The average of the vertical forces is higher than the average of the longitudinal forces and the lateral forces are markedly lower than either of the vertical or longitudinal. This pattern is closer to what was anticipated than the pattern evidenced by the T type crashes, at least as far as the lateral crash forces being markedly lower. Table 35 presents the average impact force values for the other aircraft types.

Unfortunately, a problem also exists with the magnitudes (Table 35). When a crash is very severe, the investigator may enter an arbitrarily large number, often 99 G. With the limited number of data values in each axis for each aircraft, one or two of these large values inordinately influences the average. Statistical methods could be applied to test the data as to whether these points could be discarded as outliers, but these methods were not used.

Table 34 – UH-60 Impact Severity in Aircraft Reference Frame (IT&TA, S= all)

	Z axis Vertical (G)	X axis Longitudinal (G)	Y axis Lateral (G)
Average	45.3	41.9	7.9
Standard Deviation	49.8	52.2	9.5

Table 35 –Mean Impact Severity by Aircraft Type (S= all)

	T Type Crashes				IT&TA Type Crashes		
	Vertical Decel (G) Abs. Val.	Longitudinal Decel (G) Abs. Val.	Lateral Decel (G) Abs. Val.		Vertical Decel (G) Abs. Val.	Longitudinal Decel (G) Abs. Val.	Lateral Decel (G) Abs. Val.
UH-60	18.6	27.2	15.9		45.3	41.9	7.9
UH-1	12.4	15.5	7.9		27.4	14.9	14.3
OH-58AC	12.2	16.1	16.3		12.9	35.0	17.3
OH-58D	6.7	3.7	12.3		14.1	3.7	9.7
OH-6	Insufficient data				Insufficient data		
CH-47	26.6	17.2	9.0		Insufficient data		
AH-64	16.7	16.7	12.1		19.8	26.7	10.7
AH-1	15.2	11.2	6.7		26.0	24.1	23.6

The analysis of the impact severity along the individual aircraft axes is useful for crashworthy design purposes, but it does not give a picture of the resultant impact severity vector. The magnitude of the resultant severity is calculated by combining the magnitudes of the impact force reported for each axis. The information is presented as a cumulative frequency plot for the T crashes and a second cumulative frequency plot for the IT&TA crashes. The cumulative frequency data from the UH-60 for the direct terrain impacts and the post-obstacle impacts (Figure 27 and Figure 28) are presented as examples. The data for crashes of all three survivability levels are plotted together with the data point for each crash coded for survivability. It is evident from these two figures that the severity increases smoothly from zero

to the range of 40 to 60 G, then large jumps in the severity appear. These jumps also coincide with the transition from partially survivable to non-survivable crashes. It is likely that the crash investigators have a series of damage indicators each of which corresponds to a particular severity level. Once the crash exceeds the damage level deemed survivable, these indicators are further apart and less reliable; thus, the estimates of the actual impact severity are less precise. Plots for the other aircraft are presented in Appendix F.

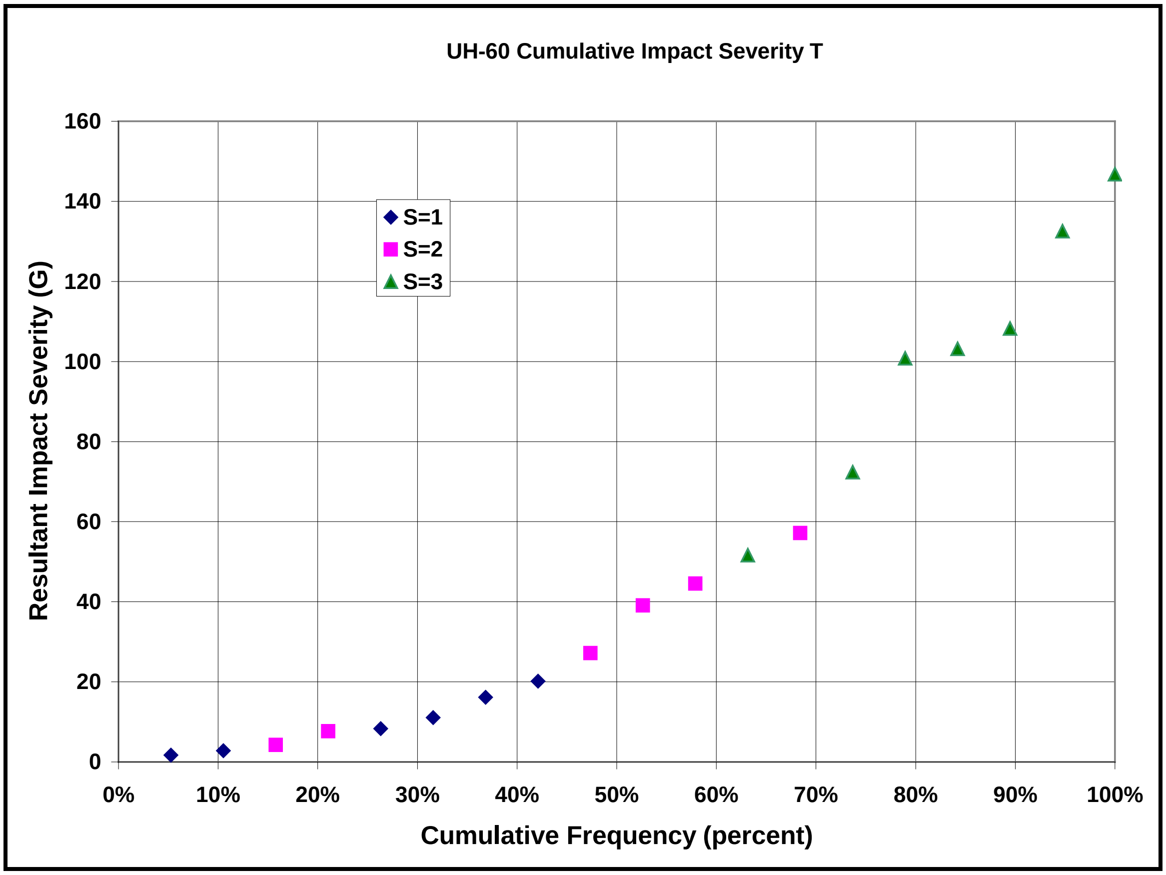

Figure 27 – UH-60 T Cumulative Frequency of Resultant Impact Force

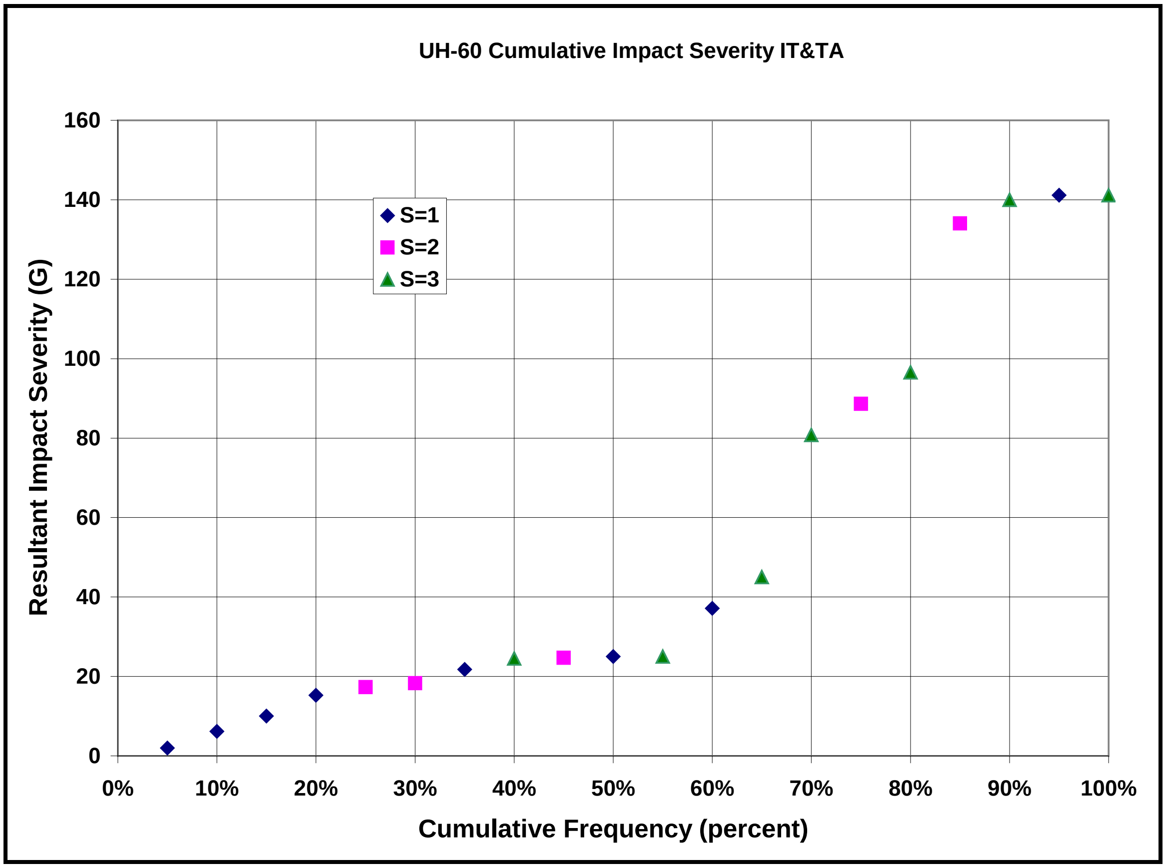

Figure 28 – UH-60 IT&TA Cumulative Frequency of Impact Force

3.4.1.2 – Rotation after Major Impact

These fields of the database are not well populated with data. The two following tables present the number of crashes for each aircraft and crash type that have at least one angle value reported. However, the pitch rotation angle in particular is seldom reported. The large values of the standard deviations indicate that there is a wide spread of values reported even for a relatively small number of events.

Table 36 – All Aircraft Rotation Angle (T Crashes)

Aircraft T crashes	# of Crashes with data	Roll Rotat. (deg) Avg. Stdev.	Yaw Rotat. (deg) Avg. Stdev.	Pitch Rotat. (deg) Avg. Stdev.
UH-60	12	-4.3	81.7	-21.3
		126.8	175.2	120.9
UH-1	17	56.8	29.6	-39.0
		140.8	97.2	44.6
OH-58AC	17	38.7	19.8	-1.0
		75.5	250.9	5.7
OH-58D	21	-1.4	44	-11.6
		93.2	152.2	19.7
OH-6	2	-5	58.3	N.A.
		N.A.	275.5	N.A.
Ch-47	6	76.3	-54.7	-11.0
		96.2	97.4	2.6
AH-64	27	59.6	46.3	-19.8
		262.5	146.7	132.9
AH-1	6	-78	3.6	-20.0
		251	56.2	N.A.

Table 37 – All Aircraft Rotation Angle (IT&TA Crashes)

Aircraft IT&TA	# of Crashes with data	Roll Rotat. (deg.) Avg. Stdev.	Yaw Rotat. (deg.) Avg. Stdev.	Pitch Rotat. (deg.) Avg. Stdev.
UH-60	6	-5.8	22	-75.8
		258.1	99.1	104.2
UH-1	4	43.8	175	-15.0
		68.2	134.4	7.1
OH-58AC	6	-156.7	-7.5	-25.0
		32.1	19.7	
OH-58D	6	-4	3	-7.0
		90.4	16.9	35.5
OH-6	0	No data	No data	No data
Ch-47	1	No data	-10	No data
			N.A.	
AH-64	13	-15.4	8.6	-21.7
		149.8	109.5	42.7
AH-1	1	5	90	No data
		N.A.	N.A.	

3.4.2 – Airframe Damage – Damage Maps

The damage to the airframe is reported by areas of the airframe such as the ROOF_COCKPIT or FLOOR_MID. The damage in each area is reported in two or three levels. For regions quantified at two levels, the levels are less than or greater than 1 foot. Where no datum is entered, it was presumed that there was no damage. Guidance in DA PAM 385-40 suggests that damage less than 3 inches in depth need not be reported unless it is associated with an injury. For analysis purposes, a blank field was treated as “no damage reported”; effectively, this added one level of damage to each aircraft area. For areas quantified in three levels, the levels are less than 1 foot, greater than 1 foot and less than 3 feet, or greater than 3 feet. Information was also reported on the deformation of the structure supporting the seat. In this case, the data describe the direction in which that structure was deformed: vertical, sideward, or longitudinal. The guideline for identifying this deformation is a distortion of at least 2 inches for one of the seat attachment points. Each damage area had a second field; that field describes whether or not the damage caused an injury.

Including the seat support structures, there are 22 areas for which damage is reported. Not all the areas were applicable on each aircraft type; consequently, combining the results for all of the aircraft will not be useful. The data for each area were grouped in four regions for plotting: roof, lateral, floor, and seat

structure. The data for direct terrain impacts were compiled separately from the impacts following in-flight obstacle strikes.

Two different approaches to interpreting this data were experimented with. The first consisting of stacked bar charts was found to be less compelling and it was only completed for the UH-60. The following section documents the preferred interpretation approach which consists of creating maps of the aircraft damage similar in concept to the injury maps.

3.4.2.1 – Damage – Maps of Damage Leading to Injury Presentation

The presentations of aircraft damage are analogous to the injury map for displaying the frequency with which various regions of the body are injured. The aircraft maps created in this analysis present only the damage that led to injuries. For each region of the aircraft, the map shows what fraction of the crashed aircraft population experienced damage that caused injury. The map for the UH-1 is presented below an example (Figure 29). The aircraft outlines are intended to be generic for each type, utility, attack, cargo, and observation. On the right side of the upper block is a legend box that identifies the specific aircraft, the type of crashes, and the number of crashes in the population. The maps present data only for survivable and partially survivable crashes. The non-survivable and unrated crashes were omitted. There are two maps for each aircraft, one for the T crashes and one for the IT&TA crashes. The maps are presented in Appendix G.

Each text box contains several pieces of information: the aircraft region, the severity of damage (d), and the percent of crashes where that level of damage contributed to an injury. In the database, damage is described in two or three levels. Roof damage has three levels beyond no damage: d > 1 ft, 1 ft<d<3 ft, and d>3 ft. Floor damage is described in two levels: d>1ft and d<1ft. Likewise, lateral damage is described in two levels: d<1 ft and d>1 ft.

Seat damage is treated differently; this field records the presence of seat mounting point deflection (d) in any of three directions: up, longitudinal, and lateral. These maps are useful for someone interested in the behavior of a particular aircraft. The behavior of a particular aircraft in the two different types of crash can be evaluated by comparing the two maps side by side.

Looking through these maps for trends across aircraft proves to be somewhat overwhelming because there are several different damage regions and because the damage is resolved into two or three discrete levels. This multi-level reporting also means that most of the percentages appear relatively small. However, the percentages in each region are additive; consequently, the relatively small values are somewhat misleading. No trends have been identified in these data. These data can benefit from further analysis.

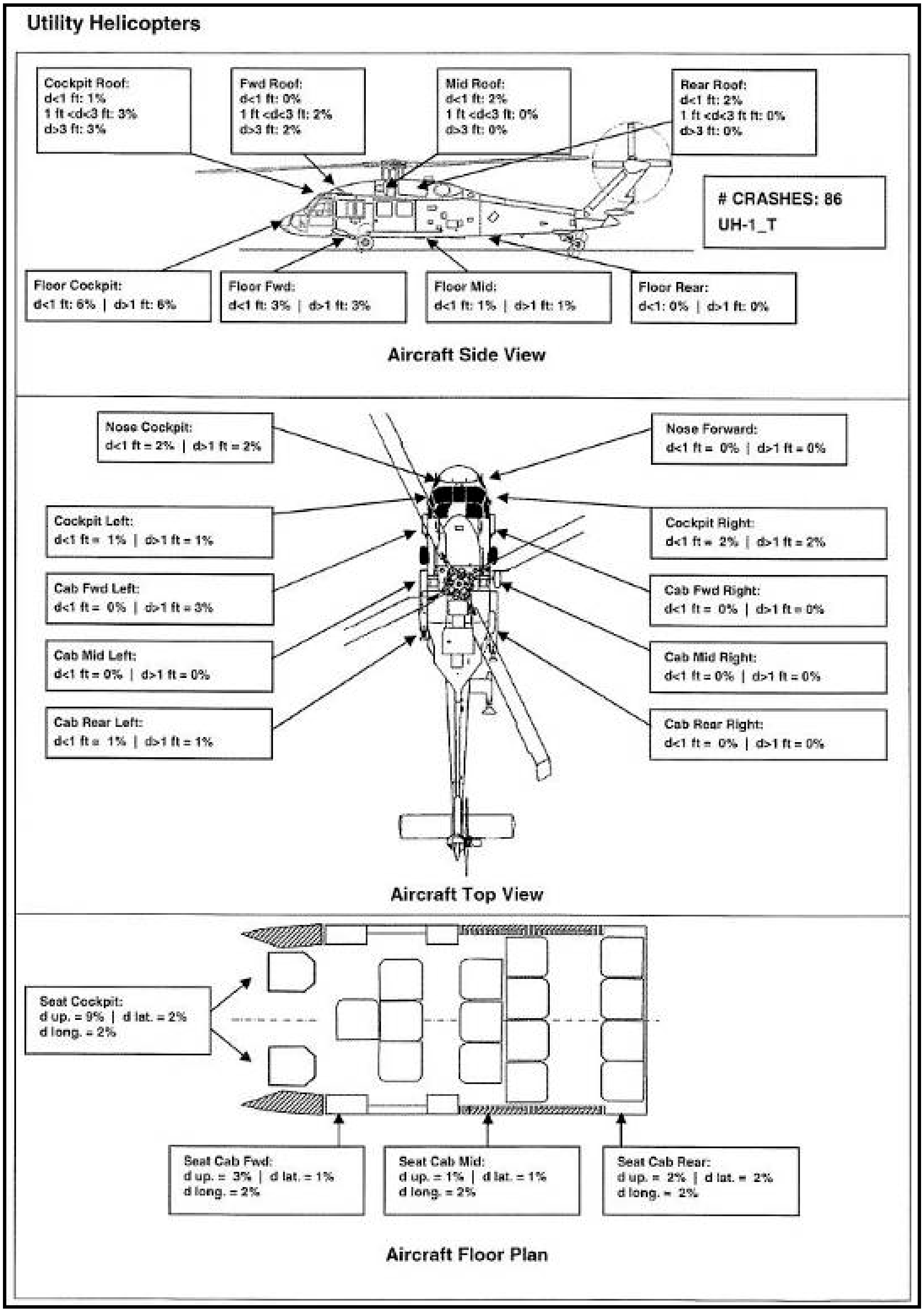

Figure 29 – Example Aircraft Damage Map

3.4.3 – Retention of High-mass Item

Retention of the high mass items is particularly important in helicopter crashworthiness because two of these items, the transmission and the main rotor system, are generally above the occupants. Block 8 of DA FORM 2397-6-R[4] contains the retention information. The post-crash location of these items is recorded in four fields reporting whether the item was: displaced, torn free, penetrated/entered cockpit, and penetrated/entered cabin. The items for which the retention is recorded are: transmission (main or forward), transmission (rear), rotor blade (main or forward), rotor blade (tail or rear), landing gear (location to be specified), and other (specify). A field is provided in the database to record the location of the landing gear that is displaced; however, there is no field to record the identity of the "Other" large item that is recorded as not retained. The query developed in this project has extracted the data on which landing gear were not retained. After studying the results of the queries, it was apparent that the retention data began to be recorded after 1 January 1987. Consequently, rather than selecting the number corresponding to all of the crashes for an aircraft type as the divisor, the number of usable crashes occurring after 31 December 1986 has been used as the divisor. Creating the frequencies in this way is intended to facilitate meaningful comparisons between different aircraft types. In the following tables, the number of crashes used as the divisor is provided in the upper left corner of the table.

The results for this segment of the study are presented as frequency tables listing the components tracked and the frequency at which they were reported in each category of retention. Considering the AH-64 as an example; for crashes directly into terrain, data in Table 38 reveal that the main transmission was displaced in 15 percent of the crashes. However, the transmission was neither torn free nor entered the cockpit in any of the crashes. The data also reveal that the landing gear is displaced 35 percent of the time and torn free in 13 percent of the crashes. The main rotor blade penetrated the cockpit in 5 percent of the crashes. When these frequencies are compared to the crashes following an inflight obstacle strike (see Table 39), higher frequencies of large item movement are apparent in the post-strike crashes. A main rotor blade is torn free in 57 percent of the post-strike crashes compared to 33 percent for the terrain impacts. Additionally, the landing gear is much more likely to displaced or torn free. Interestingly, there were no main rotor blade strikes to the cockpit in the post-strike crashes.

Table 38 – AH-64 Frequency of Large Component Movement in T Impacts

AH-64 T (40 crashes) Component	Displaced (Percentage Crashes after 12/86)	Torn-free (Percentage Crashes after 12/86)	Penetrated Cockpit (Percentage Crashes after 12/86)	Penetrated Cabin (Percentage Crashes after 12/86)
Transmission Main or fwd	15%	0%	0%	0%
Transmission Rear	0%	3%	0%	0%
Rotor Blade Main or fwd	8%	33%	5%	0%
Rotor Blade Tail or rear	13%	20%	0%	0%
Landing Gear	35%	13%	0%	0%
Other			0%	0%

Table 39 – AH-64 Frequency of Large Component Movement in IT&TA Crashes

AH-64 T (23 crashes) Component	Displaced (Percentage Crashes after 12/86)	Torn-free (Percentage Crashes after 12/86)	Penetrated Cockpit (Percentage Crashes after 12/86)	Penetrated Cabin (Percentage Crashes after 12/86)
Transmission Main or fwd	22%	4%	0%	0%
Transmission Rear	0%	9%	0%	0%
Rotor Blade Main or fwd	26%	57%	0%	0%
Rotor Blade Tail or rear	13%	48%	0%	0%
Landing Gear	52%	30%	0%	0%
Other			4%	0%

An inter-generational comparison can be made between the AH-64 and its predecessor, the AH-1. Comparing the data for the T crashes (Table 38 and Table 40) between the two aircraft types, the AH-1 experienced higher frequencies of main transmission displacement and separation. Additionally, the landing gear was displaced or torn free more often on the AH-1 (the AH-1 has skid landing gear, while the AH-64 has wheel and strut landing gear). The two aircraft have similar frequencies for main rotor displacement, but the AH-1 actually loses a blade as a result of a crash only about half as often as the AH-64. The AH-64 reported no main rotor blades penetrating the cockpit in 23 crashes, whereas the AH-1 experienced one penetration in 13 crashes.

Table 40 – AH-1 Frequency of Large Component Movement in T Crashes

AH-1 T (13 crashes) Component	Displaced (Percentage Crashes after 12/86)	Torn-free (Percentage Crashes after 12/86)	Penetrated Cockpit (Percentage Crashes after 12/86)	Penetrated Cabin (Percentage Crashes after 12/86)
Transmission Main or fwd	31%	8%	0%	0%
Transmission Rear	0%	8%	0%	0%
Rotor Blade Main or fwd	8%	15%	8%	0%
Rotor Blade Tail or rear	0%	0%	0%	0%
Landing Gear	46%	31%	8%	0%
Other			8%	0%

3.5 – Site Query

The purpose of the site query is to extract information describing the environment into which the aircraft impacted. The information is divided into three categories, terrain, surface, and obstacles. In the words of Army Pamphlet 385-40[3], the terrain features are "general characteristics" pertaining to the "dominant terrain features surrounding the crash site." More than one descriptor may apply. The terrain block offers

the broad geographic descriptors: mountain, desert, rolling, flat, and water. "Surface conditions" are those "on which the aircraft made its ground run and/or came to final rest." The investigator can characterize the surface by one or more of the six choices: prepared, ice, sod, snow, soggy, and water. Obstacles "pertain to obstacles located in the vicinity of the accident site that may have influenced the accident." The investigator is offered the following choices: stumps, trees, buildings, wires, rocks, and other. The investigator may mark all that apply. Overall, at least one response was provided for the terrain in about 85 percent of the records. Likewise, about 85 percent of the records provided responses describing the surface. However, only 58 percent of the records had at least one response for obstacles.

3.5.1 – Surface

The six terms describing the surface encompass a broad range of possibilities with just six choices for the investigator: Prepared, Ice, Sod, Snow, Soggy, and Water. Each of these choices is a field in the database and is coded either Y for yes or N for no. Occasionally an investigator will mark two boxes often using "Soggy" as an adjective. The most common combination was "soggy sod." For purposes of analysis, "Soggy Sod" was simplified to "soggy." The surface parameter is the only one in this group for which the data were simplified to one response per crash.

The importance of the impact surface lies in how the aircraft interacts with the surface. In cases of high vertical velocity, a hard surface provides the best opportunity for energy absorbing landing gear to be effective. In cases of substantial horizontal velocity, a hard surface provides the best opportunity for a long, low deceleration slide out. Conversely, the softer surfaces negate some of the effect of an energy absorbing landing gear by allowing the gear to penetrate the surface without absorbing the intended amount of energy. For horizontal velocity cases, soft terrain allows the landing gear to penetrate the surface, leading to an overturning moment on the aircraft. Once the aircraft belly contacts the ground, a soft surface is more prone to plowing resulting in high deceleration rates. As recorded in the database, water is problematic in that there is no provision for listing the depth of the water. On occasions where water was combined with another surface such as Sod, the summary narrative was reviewed and the action was generally to revise the data to be "Soggy." Where it was apparent that there was a shallow layer of water over another surface, the lower surface was reported.

The following tables show that sod is the most frequent impact surface of the choices on the form. This finding is across all aircraft types and both levels of survivability: survivable (S=1&2) and non-survivable (S= 3) and over both types of terrain impacts (T and IT&TA). For survivable and partially survivable impacts directly into terrain (Table 41), sod is the impact surface in 66 percent of the crashes that report a surface. Sod is 58 percent of all the usable crashes of this type. The next most frequent surface is prepared at 16 percent (14 percent of the usable crashes in the group). Impacting an obstacle prior to impacting terrain did not substantially change the relative frequency of crashes onto sod (Table 42). As might be expected, fewer of these crashes occurred onto Prepared surfaces. More of these crashes occurred into a soggy surface than did crashes directly into the terrain.

Table 41 – Surfaces Recorded for Survivable Crashes Directly into Terrain

Aircraft T S=1&2	Prepared	Ice	Sod	Snow	Soggy	Water	Crashes Surface Reported	Crashes Usable
UH-60	5	0	13	0	2	3	23	26
UH-1	8	0	49	11	6	2	76	84
OH-58AC	6	0	42	3	5	2	58	67
OH-58D	5	0	15	0	3	0	23	27
OH-6	5	0	19	0	5	0	29	28
CH-47	1	1	10	0	2	0	14	17
AH-1	12	0	33	0	4	0	49	58
AH-64	6	0	17	0	3	0	26	32
Total	48	1	198	14	30	7	298	339
Percent/Rptd	16.1	0.3	66.4	4.7	10.1	2.3	-	
Percent/Usable	14.2%	0.3%	58.4%	4.1%	8.8%	2.1%	87.9%	100%

Table 42 – Surfaces Recorded for Survivable Crashes into Terrain following an Obstacle Strike

Aircraft IT&TA S=1&2	Prepared (#)	Ice	Sod	Snow	Soggy	Water	Crashes Surface Reported	Crashes Usable
UH-60	1	0	5	2	4	0	12	15
UH-1	3	3	20	1	10	1	38	45
OH-58AC	2	0	17	0	5	0	24	30
OH-58D	1	0	5	0	2	0	8	10
OH-6	0	0	0	0	1	0	1	1
CH-47	0	0	0	0	0	0	0	2
AH-1	0	0	13	0	4	1	18	21
AH-64	3	0	16	0	0	0	19	19
Total	10	3	76	3	26	2	120	143
Percent/Rptd	8.3	2.5	63.3	2.5	21.7	1.7	-	
Percent/Usable	7.0%	2.1%	53.1%	2.1%	18.2%	1.4%	83.9%	100%

The general trend is similar for the non-survivable crashes, although the differences may suggest some interesting conclusions. The data on non-survivable crashes in Table 43 reveals that an even higher

percentage of the non-survivable crashes directly into terrain occurred on sod when compared to the survivable crashes of the same type. Interestingly, the frequency of non-survivable crashes directly into terrain on prepared surfaces was extremely low (1.9 percent compared to 16.1 percent). The frequency of non-survivable crashes into water was also somewhat higher than the comparable survivable crashes. The crashes following an obstacle strike also fell on sod 69 percent of the time. The data presented in Table 44 reveal that most of the remainder (29 percent) of these crashes occurred onto soggy surfaces. This group (IT&TA) had the largest frequency of impacts onto soggy surfaces.

Table 43 – Surfaces Recorded for Non-survivable Crashes Directly into Terrain

Aircraft T S= 3	Prepared (#)	Ice	Sod	Snow	Soggy	Water	Crashes Surface Reported	Crashes Usable
UH-60	1	0	7	1	1	1	11	11
UH-1	0	0	12	0	2	1	15	17
OH-58AC	0	0	9	0	1	0	10	11
OH-58D	0	0	1	0	0	1	2	3
OH-6	0	0	0	0	0	0	0	0
CH-47	0	0	2	0	1	0	3	3
AH-1	0	0	5	0	1	0	6	6
AH-64	0	0	6	0	0	0	6	6
Total	1	0	42	1	6	3	53	57
Percent/Rptd	1.9	0	79.2	1.9	11.3	5.7	-	
Percent/Usable	1.8%	0.0%	73.7%	1.8%	10.5%	5.3%	93.0%	

Table 44 – Surfaces Recorded for Non-survivable Crashes Following an Obstacle Impact

Aircraft IT&TA S=3	Prepared (#)	Ice	Sod	Snow	Soggy	Water	Crashes Surface Reported	Crashes Usable
UH-60	0	0	5	0	2	0	7	8
UH-1	0	0	3	1	0	0	4	6
OH-58AC	0	0	8	0	0	0	8	9
OH-58D	0	0	1	0	1	0	2	2
OH-6	0	0	0	0	1	0	1	2
CH-47	0	0	0	0	1	0	1	1
AH-1	0	0	2	0	3	0	5	5
AH-64	0	0	2	0	1	0	3	4
Total	0	0	21	1	9	0	31	37
Percent/Rptd	0	0	67.7	3.2	29	0	-	
Percent/Usable	0.0%	0.0%	56.8%	2.7%	24.3%	0.0%	83.8%	

The very low number of non-survivable crashes that occur on prepared surfaces is a notable finding. One might hypothesize that energy absorbing landing gear were more effective on prepared surfaces and,

consequently, there were fewer non-survivable crashes (i.e., the crashes on prepared surfaces were more likely to be survivable) on prepared surfaces. As a first test for this hypothesis, all of the crashes were grouped together regardless of whether they were directly into terrain or post-obstacle impacts (Table 45). Combining the data for the two types of crashes does not change the trends. Frequency of non-survivable crashes on prepared surfaces remains extremely small. In Table 45, comparing the frequencies for the surfaces other than Prepared, only the frequency on sod differs markedly between the two crash survivability groups.

Table 45 – Frequency of Crashes on Surfaces Grouped by Survivability

Crashes	Prepared	Ice	Sod	Snow	Soggy	Water	Crashes Surface Reported
T + IT&TA, S=1&2 (#)	58	4	274	17	56	9	418
Percent/Rptd (418)	13.9%	1.0%	65.6%	4.1%	13.4%	2.2%	
Percent/Usable (482)	12.0%	0.8%	56.8%	3.5%	11.6%	1.9%	
T + IT&TA, S= 3 (#)	1	0	63	2	15	3	84
Percent/Rptd (84)	1.2%	0.0%	75.0%	2.4%	17.9%	3.6%	
Percent/Usable (94)	1.1%	0.0%	67.0%	2.1%	16.0%	3.2%	

To further test the hypothesis regarding the efficacy of energy absorbing landing gear, the same surface impact data can be segregated according to the type of landing gear with which the aircraft is equipped. If the landing gear *type* influences the outcome of the crash, then regrouping the data in this way may lead to a difference between the two aircraft groups in the frequency of non-survivable crashes on prepared surfaces. Testing the hypothesis in this way was foiled by a lack of data. As can be seen in Table 46, there were usable numbers of survivable crashes on prepared surfaces. The percentage of survivable accidents occurring on prepared surfaces did not differ markedly between the two landing gear types, although the EA landing gear did have a higher frequency of survivable crashes. The EA landing gear having a higher frequency of survivable crashes is in the direction hypothesized. Only one non-survivable crash occurred on a prepared surface and, as it happens, that was an aircraft with an EA landing gear. Consequently, little can be inferred from comparing the data for the non-survivable crashes. Demonstrating the efficacy of the EA landing gear will necessitate a detailed study of the injury data.

Table 46 – Frequency of Surface Impacted by Landing Gear Type

	Prepared	Ice	Sod	Snow	Soggy	Water	Crashes Surface Reported
Aircraft w/ EA LG, All S= 1&2 (#)	15	0	51	2	9	3	80
Percent	18.8%	0.0%	63.8%	2.5%	11.3%	3.8%	
Aircraft w/o EA LG, All S= 1&2 (#)	42	3	213	15	45	6	324
Percent	13.0%	0.9%	65.7%	4.6%	13.9%	1.9%	
Aircraft w/ EA LG, All S= 3 (#)	1	0	20	1	4	1	27
Percent	3.7%	0.0%	74.1%	3.7%	14.8%	3.7%	100.0%
Aircraft w/o EA LG, All S= 3 (#)	0	0	41	1	9	2	53
Percent	0.0%	0.0%	77.4%	1.9%	17.0%	3.8%	100.0%

The 1989 ACSDG[2] reported data on the surfaces impacted based on US Army crashes occurring during the period FY1980-FY1985. The current study likely includes many of the same mishaps included in the 1989 study (Table 47). Looking at the percentages within each study, there are no dramatic differences. The fraction of crashes that occurred onto prepared surfaces in this study remained approximately equal to the fraction in the previous study. The percentage of crashes on Sod is higher in the current study than in the 1989 study, whereas the percentage of crashes onto soggy surface is lower in the current study.

Table 47 – Comparison of Impact Surfaces in Current and 1989 Study

	Number of Aircraft 1989 Study (T, S=All)	Number of Aircraft Current Study	Percentage of Responses 1989 Study (T, S=All)	Percentage of Responses Current Study
Prepared Surface	33	49	13.0	14.0
Sod	160	240	63.0	68.4
Soggy	38	36	15.0	10.3
Ice	3	1	1.2	0.3
Snow	16	15	6.3	4.3
Water	4	10	1.6	2.8
Total	254	351	100.1	100.1

3.5.2 – Terrain

The impact surface undoubtedly has the most direct effect on the efficacy of the landing gear and hence the outcome of the crash. A less significant parameter within this group of variables is arguably the terrain. For reporting purposes, the terrain is described by one of five descriptors: Mountain, Desert, Rolling, Flat, and Water. The data are presented in groups related to whether the impact was direct to terrain or following an obstacle strike, the survivability and the aircraft type. Table 48 presents the data for crashes directly into terrain and Table 49 presents the data for crashes following an obstacle impact. All of the terrain characteristics reported were retained unless the information was redundant or contradictory. The number of crashes on each terrain type is also expressed as two percentages: first, the percentage relative to the number of crashes for which at least one terrain was reported and second, the percentage relative to the number of usable crashes.

The single feature that stands out for data in Table 48 is the difference in most frequent terrain type between the S=1&2 group and the S=3 group. The more survivable group has a flat terrain impact frequency of 52 percent, whereas only 22 percent occur on rolling terrain. In contrast, the non-survivable group has virtually the reverse frequencies of impact, with 51 percent being onto rolling terrain and only 20 percent onto flat terrain.

Table 48 –Number Terrain Types Reported on for Crashes Directly into Terrain

T, S= 1&2	GC_ MOUNTAIN	GC_ DESERT	GC_ ROLLING	GC_ FLAT	GC_ WATER	# of Crashes Reporting at Least One Terrain	# of Usable Crashes of This Type
UH-60	3	5	4	12	3	24	25
UH-1	14	8	14	38	3	73	84
OH-58AC	5	14	18	28	4	63	67
OH-58D	0	11	2	18	0	27	27
OH-6	2	0	6	15	2	25	29
CH-47	3	6	5	6	0	17	17
AH-64	5	13	3	19	0	31	32
AH-1	5	8	13	22	2	43	57
Total	37	65	65	158	14	303	338
Percent/Rptd	12.2%	21.5%	21.5%	52.1%	4.6%		
Percent/Usable	10.9%	19.2%	19.2%	46.7%	4.1%		
T, S= 3							
UH-60	2	2	3	3	1	10	11
UH-1	1	3	7	3	1	14	17
OH-58AC	3	2	6	0	1	11	11
OH-58D	0	0	2	0	1	3	3
OH-6	0	0	0	0	0	0	1
CH-47	0	0	1	1	0	2	3
AH-64	0	2	4	2	0	6	6
AH-1	1	0	3	1	0	5	6
Total	7	9	26	10	4	51	58
Percent/Rptd	13.7%	17.6%	51.0%	19.6%	7.8%		
Percent/Usable	12.1%	15.5%	44.8%	17.2%	6.9%		

Table 49 – Number of Terrain Types Reported for Crashes Following Obstacle Strike

IT&TA, S= 1&2	GC_ MOUNTAIN	GC_ DESERT	GC_ ROLLING	GC_ FLAT	GC_ WATER	# of Crashes Reporting at Least One Terrain	# of Usable Crashes of This Type
UH-60	3	0	4	6	0	12	21
UH-1	12	1	13	10	3	37	19
OH-58AC	6	3	12	3	1	22	30
OH-58D	2	2	3	3	0	9	10
OH-6	0	0	1	0	0	1	1
CH-47	2	0	0	0	0	2	2
AH-64	1	1	12	6	0	18	19
AH-1	2	1	8	4	0	15	21
Total	28	8	53	32	4	116	123
Percent/Rptd	24.1%	6.9%	45.7%	27.6%	3.4%		
Percent/Usable	22.8%	6.5%	43.1%	26.0%	3.3%		
IT&TA, S= 3							
UH-60	1	1	5	2	0	7	8
UH-1	1	0	4	0	0	5	6
OH-58AC	2	1	5	1	1	9	10
OH-58D	0	1	2	0	0	2	2
OH-6	0	0	2	0	0	2	2
CH-47	0	0	0	1	0	1	1
AH-64	1	0	4	0	0	4	4
AH-1	1	0	1	4	0	6	5
Total	6	3	23	8	1	36	38
Percent/Rptd	16.7%	8.3%	63.9%	22.2%	2.8%		
Percent/Usable	15.8%	7.9%	60.5%	21.1%	2.6%		

The 1989 ACSDG[2] reported data on the terrains impacted based on US Army crashes occurring during the period FY1980 – FY1985. For comparison purposes, Table 50 presents the results from this report on terrains impacted in comparison with those reported from the previous study. Although this study undoubtedly included some of the same crashes, there seemed to be more dramatic shifts in the terrains impacted than there were in the surfaces impacted. The percentage of responses citing flat terrain increased, as did the percentage of responses citing desert. The percentage of responses citing rolling terrain and mountains both decreased from the earlier study to the present one.

Table 50 – Terrain Impacted Compared to 1989 Study

	Number of Aircraft 1989 Study	Number of Aircraft Current Study (T, S=All)	Percentage of Responses 1989 Study	Percentage of Responses Current Study (T, S=All)
Flat	84	168	34.7	42.5
Water	14	18	5.8	4.6
Rolling	78	91	32.2	23.0
Desert	18	74	7.4	18.7
Mountains	48	44	19.8	11.1
Total	242	395	99.9	99.9

3.5.3 – Obstacles

First, it should be noted that these obstacles differ from those actually struck by the aircraft prior to impacting the terrain. These obstacles are a part of characterizing the impact site. As described in DA PAM 385-40, the obstacles choices in Block 20d of DA FORM 2391-1-R pertained "to obstacles located in the vicinity of the accident site that may have influenced the accident." The instructions also note that more than one may apply. The obstacle choices offered are: Stumps, Trees, Buildings, Wires, Rocks, and Other. The fraction of usable crashes for which obstacles were reported was lower than the fractions reported for terrains or for surfaces. Approximately 85 percent of the usable crashes reported terrains and surfaces. Only 40 percent of the usable T crashes reported obstacles and only 68 percent of the IT&TA crashes reported obstacles.

The following tables report the number of crashes for which each type of obstacle was reported. The percentages were calculated based on the total number of usable crashes. This method presumes that the absence of reported obstacles for a particular crash corresponds to the actual absence of obstacles at the crash site rather than the investigator's omission.

For crashes directly into terrain, the data in Table 51 indicate that pilots in emergency situations have obstacles to deal with in about half of the survivable cases. In the non-survivable accidents, the aircraft were in the vicinity of trees in more than half the cases. These obstacles were sometimes noted in the narrative by statements indicated that the pilot's preferred landing site was unavailable due to an obstacle on the site or between the preferred landing site and the aircraft's approach position. An example of the latter situation might be a wire across a road. It is readily apparent that obstacles occur far more frequently on the non-survivable crash sites. In particular, trees were reported in the vicinity of non-survivable crashes at three times the frequency as was reported near-survivable crashes.

Table 51 – Frequency of Obstacles Struck by Aircraft Crashing Directly to Terrain (T)

T, S= 1&2	OSC_ STUMPS	OSC_ TREES	OSC_ BUILDINGS	OSC_ WIRES	OSC_ ROCKS	OSC_ OTHER	# of Crashes with at Least One Obstacle Identified	# of Usable Crashes
UH-60	0	7	4	1	4	5	15	25
UH-1	1	12	3	5	6	12	34	84
OH-58AC	0	11	1	0	9	9	29	67
OH-58D	1	6	0	1	1	2	9	27
OH-6	0	2	1	0	0	1	3	29
CH-47	0	3	0	1	5	6	14	17
AH-64	0	10	1	3	5	3	18	32
AH-1	0	4	2	3	4	4	17	57
Total	2	55	12	14	34	42	139	338
Percent/Rptd	1.4%	39.6%	8.6%	10.1%	24.5%	30.2%		
Percent Usable	0.6%	16.3%	3.6%	4.1%	10.1%	12.4%		
T, S= 3								
UH-60	0	2	1	0	2	1	5	11
UH-1	0	6	0	2	1	4	11	17
OH-58AC	0	6	0	0	4	1	9	11
OH-58D	0	0	0	0	0	1	1	3
OH-6	0	0	0	0	0	0	0	1
CH-47	0	2	0	1	0	1	3	3
AH-64	0	5	0	0	2	0	5	6
AH-1	0	1	0	0	3	1	5	6
Total	0	22	1	3	12	9	39	58
Percent/Rptd	0.0%	56.4%	2.6%	7.7%	30.8%	23.1%		
Percent Usable	0.0%	37.9%	1.7%	5.2%	20.7%	15.5%		

The interpretation of the obstacle statistics for crashes following an obstacle strike is less obvious. The frequency of survivable crashes occurring near trees and the frequency of non-survivable crashes is about equal. Note that there were only 38 usable crashes in the non-survivable group. Hence, each crash affected the percentages by nearly 3 percent.

Table 52 – Obstacles Struck by Aircraft Crashing After an Obstacle Strike

IT&TA, S= 1&2	OSC_ STUMPS	OSC_ TREES	OSC_ BUILDINGS	OSC_ WIRES	OSC_ ROCKS	OSC_ OTHER	# of Crashes with at least one Obstacle Identified	# of Usable Crashes
UH-60	0	11	1	4	0	0	12	21
UH-1	2	22	2	6	10	4	37	19
OH-58AC	1	15	1	4	6	5	25	30
OH-58D	1	6	0	1	1	2	9	10
OH-6	0	0	0	0	1	0	1	1
CH-47	1	1	0	0	1	0	2	2
AH-64	4	15	1	3	3	1	19	19
AH-1	0	18	0	1	1	0	5	21
Total	9	88	5	19	23	12	110	123
Percent/Rptd	8.2%	80.0%	4.5%	17.3%	20.9%	10.9%		
Percent Usable	7.3%	71.5%	4.1%	15.4%	18.7%	9.8%		
IT&TA, S= 3								
UH-60	0	6	1	2	1	0	8	8
UH-1	0	5	0	0	1	0	6	6
OH-58AC	0	5	0	2	4	0	9	10
OH-58D	0	1	0	0	1	0	2	2
OH-6	0	1	0	1	0	0	2	2
CH-47	0	1	0	0	0	0	1	1
AH-64	0	3	0	2	1	0	4	4
AH-1	0	4	0	0	0	0	5	5
Total	0	22	1	7	8	0	37	38
Percent/Rptd	0.0%	59.5%	2.7%	18.9%	21.6%	0.0%		
Percent/Usable	0.0%	57.9%	2.6%	18.4%	21.1%	0.0%		

3.6 – Injury Query

The data from the Safety Center contained injury information in two different tables: INJURY_INFORMATION and AIRCRAFT_INFORMATION. The data in the latter table is limited to counts of the number of people injured at several severity levels including: fatal, missing, totally disabled, partially disabled, and other injuries. These counts were broken out into counts of military personnel and civilian personnel and also by whether or not the person was an occupant of the aircraft. Descriptive information about the individuals, the injuries, and the injury causation is contained in the INJURY_INFORMATION table. Generally speaking, more crashes had data reported in the AIRCRAFT_INFORMATION table than in the INJURY_INFORMATION table. The data in both tables have been analyzed because there are insights and information to be gained from both.

The discrepancies between the two sources of data are indicated by the values in Table 53. The explanation for the discrepancies is not evident from looking through this summary table. In the data for individual aircraft, the author found no discernable patterns that might explain the differences in numbers of injuries reported. Considering the number of crashes that the injury numbers are drawn from does not explain the differences. In several cases, more injuries are reported for fewer crashes. The tables for the individual aircraft types used to build up the table below can be found in Appendix K. The INJURY_INFORMATION in Table 53 does not report uninjured personnel; consequently, this part of the data provides no information about the total number of people on board the aircraft. The AIRCRAFT_INFORMATION in Table 53 does provide information on the number of uninjured personnel and, consequently, we can calculate the total number of personnel on board the aircraft. The data in the upper part of this table are taken either directly or indirectly from the respective database tables. In addition to these data, three parameters are calculated using the numbers in the upper part of Table 53: severely injured people per crash, total injured per crash, and the total number of people per crash. For the INJURY_INFORMATION table, these calculated values indicate that severe injuries characterize a relatively small fraction of all injuries. The total number of people injured per crash is significantly larger than the number severely injured per crash. Conversely, the AIRCRAFT_INFORMATION table indicates that severe injuries represent the majority of injuries reported in this area of the database. The total number of people injured per crash is only slightly larger than the number severely injured. The number of people per crash is markedly larger than the total injured indicating that a substantial number are uninjured according to this record of the injuries. Furthermore, the average number of people per crash indicates that the reported numbers are significantly undercounted. An average over all the crashes and aircraft type of only 1.4 persons on-board seems very unlikely. In particular, the average total people per crash for the IT&TA crashes being equal to one is not possible, considering that a crash cannot occur with less than one person aboard.

Table 53 – Source Comparison of Injury Data for All Aircraft Combined

Injury Data for S=1&2 Crashes	INJURY_INFORMATION Database Table			AIRCRAFT_INFORMATION Database Table		
Injury Type	T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)	T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)
Fatal & Missing	49	61	110	23	29	52
Total & Partially Disabling Injured	23	19	42	151	66	217
Others Injured	429	277	706	88	25	113
Total Severely Injured	72	80	152	174	95	269
Total People Injured	501	357	858	262	120	382

3.6.1 – Injury Rates

Various sections of this report have found that direct-to-terrain crashes differ from post-obstacle crashes. It is important know if these differences in the crash characteristics lead to a difference in crash outcomes and especially in injuries. As one measure of injury outcome, the number of severe injuries per crash has been calculated for each injury type, using both sources of injury data. Table 54 reports the results of

these calculations. The data from the INJURY_INFORMATION table indicates that the injury rate is higher in the post-obstacle crashes in all aircraft except the CH-47. The value for the CH-47 IT&TA crashes is based upon only two crashes. The data from the AIRCRAFT_INFORMATION table is less definitive. This data indicates that the injury rate is equal to or higher for the IT&TA crashes. The UH-1 and the CH-47 are exceptions to the trend. The CH-47 verifies the data from the other source, but the UH-1 is a reversal compared to the other data source.

Table 54 – Severe Injury Rates

	INJURY_INFORMATION Data		AIRCRAFT_INFORMATION Data	
	T crashes (Severe Injuries per crash)	IT&TA crashes (Severe Injuries per crash)	T crashes (Severe Injuries per crash)	IT&TA crashes (Severe Injuries per crash)
AH-1	0.2	0.3	0.1	0.1
AH-64	0.3	0.4	0.8	0.9
CH-47	0.9	0.5	0.9	0
OH-6	0	0	0	0
OH-58A/C	0.1	0.5	0.3	0.3
OH-58D	0.1	0.6	0.6	1.1
UH-1	0.2	0.6	0.5	0.4
UH-60	1.8	2.7	2.1	2.6

These data confirm the anticipated hypothesis that the post-obstacle crashes are more injurious than the direct-to-terrain crashes.

3.6.2 – Injury Maps

In general, the injury information of greatest interest is the data for those crashes which were considered to have been potentially survivable. The injury data have been sorted to isolate just those injuries that occurred in survivable crashes and the data are also sorted between those resulting from terrain (T) crashes and those resulting from post-obstacle-strike crashes (IT&TA). The injury data have been broken out by the role of the injured individual. The individuals have been assigned to one of three groups: pilots, other crew, or passengers. The role "pilot" includes any person with a role likely to be occupying a pilot's seat. These roles include pilot, copilot, instructor pilot, check pilot, and maintenance test pilot. The crew role includes any person who was expected to fly with the aircraft as part of a regular crew and may have a specific seat on the aircraft. All other role descriptors were assigned to the "passenger" role. Statistics for injuries were gathered around these three groups.

Injury maps similar to those appearing in the '79 ACSDG have been prepared for each aircraft type and these can be found in Appendix H. These injury maps plot the frequency of injury as a percentage of all injuries that were reported. Multiple injuries in the same region (e.g., multiple vertebral injuries) will increase the frequency for that body region. A second set of maps was created that counts the number of people injured in each body region. This latter approach to the injury frequency provides a different look at the injury distribution. This look gives insight into the number of people injured rather than the number of injuries that occurred. This view can be used to estimate the number of people who would be saved by a mitigation strategy rather than the number of injuries avoided. For example, the installation of an energy absorbing seat might prevent three lumbar fractures for the copilot, but that is one person who has avoided serious injury, not three. The two sets of injury maps can be found in Appendix H. There is a map for each of the eight aircraft types reporting the terrain (T) impacts and a map for each aircraft type reporting the post-obstacle (IT&TA) impacts.

3.6.3 – Injury Mechanisms & Causation

The INJURY_INFORMATION table records data on the mechanisms and causation for each injury to an individual. These data were assembled by aircraft type, crash type and by occupant type (pilot, crew or passenger). Tables presenting these data appear in Appendix J. These tables present the three most frequent injuries recorded for each occupant type, the three most frequent mechanisms leading to those injuries, and the three most frequent causes.

3.7 – Fire Query

The fire query records the type of fire, in-flight, or post-crash. The fire query covers information on whether or not a fire occurred, presence of crashworthy fuel systems, efficacy of the crashworthy fuel system. This query pulls information on whether or not the aircraft was carrying an auxiliary fuel system, internal or external and crashworthy or not. Provision is available to record the type of fuel in use at the time of the crash.

3.7.1 – Fire Injuries

The data collected in this study indicate that the crashworthy fuel systems have virtually eliminated burns as cause of injury in U.S. Army crashes. Using the detailed injury data from the table INJURY_INFORMATION, only 18 people were listed as having fatal burn injuries out of 848 individuals with reported injuries. In addition to the 18 fatalities, 4 people had burns that resulted in disabling injuries, and 5 people had burns considered minor injuries.

Of the 18 burn fatalities, 16 were attributed to two UH-60 crashes, each recording 8 fatalities. One crash occurred directly into terrain with an internal, auxiliary fuel system breaking away leading to a post-crash fire. The auxiliary fuel system was "definitely" the source of the combustible material. The report also noted that the emergency fuel shut-off was "not accomplished." The other crash was a terrain impact following a collision with an inflight obstacle. In this crash, a non-crashworthy external fuel system broke away. Both the external system and the main fuel system were listed as "definitely" the source of combustible material. Again, the Emergency Fuel Shut-off System was NOT effective.

Table 55 provides the detailed data on fire-related injuries experienced by each aircraft type. It is readily apparent that fire has not been a significant contributor to fatalities or disabling injuries over the period of this investigation. Measured either against the total number of people reported injured or the number of crashes in which injuries were reported, the frequency of burns is very small.

Table 55 – Count of Burn Injuries by Aircraft and Crash Type

Aircraft	# People w/ Fatal Burns	# People w/ Disabling Burns	# People w/ Minor Burns	Total People w/ Burns	Total People Reported Injured	# of Crashes
AH-64 T	0	0	0	0	31	18
AH-64 IT&TA	1	0	1	2	29	17
AH-1 T	0	0	0	0	48	29
AH-1 IT&TA	0	0	0	0	28	16
CH-47 T	0	0	1	1	60	14
CH-47 IT&TA	1	0	0	1	5	2
OH-6 T	0	0	0	0	55	15
OH-6 IT&TA	0	0	0	0	1	1
OH-58AC T	0	0	0	0	78	50
OH-58AC IT&TA	2	1	0	3	48	24
OH-58D T	0	0	0	0	27	15
OH-58D IT&TA	1	0	0	1	18	8
UH-1 T	0	1	1	2	153	56
UH-1 IT&TA	1	0	0	1	137	37
UH-60 T	4	2	2	8	77	17
UH-60 IT&TA	8	0	0	8	53	11
Total	18	4	5	27	848	330

So few accidents occurred with fire leading to injuries, that there appears to be little to be gained from studying trends in these accidents. Each aircraft type had at most two crashes which caused burn injuries. While it is certainly valuable to study those crashes where burns did occur, more will be learned by studying them as exceptions.

3.8 – Protection Equipment Query

Protection equipment covers items such as seats, restraints, helmets, survival gear, and radios. The information recorded includes such data as whether use was required, whether the item was in use at the time of the crash, and the efficacy of the item in preventing or reducing injury. The duty of the individual assigned the equipment is recorded as is the injury severity associated with the item and that person. There is a field available for recording whether the item actually "produced" an injury. Detailed tables of these data for each aircraft type are presented in Appendix M.

The protection equipment data that was analyzed includes lap belts, shoulder harnesses, inertia reels, and seats. The detailed results of the query are presented by aircraft type in Appendix M. Once again, the personnel duty identifications have been simplified to three categories: pilot, crew, and passengers. For

the discussions below, the three populations were simplified to two: pilots and cabin personnel. In the following analysis, the number of cases for each item is given. The number of times that the device was reported to have not functioned is given rather than the number of times that it functioned. In general the devices are highly reliable and so the failures are more remarkable than the successful functioning. The effect of each device on injury is reported at four levels: prevented, reduced, allowed, or produced injury. It appears from the data that some of individual items were assigned more than one level of contribution because the sum of the four levels often exceeds the number reported. Consequently, the following discussion will include counts for only the two extreme values: “prevented injury” or “produced injury.”

Table 56 presents the results for lap belts worn by pilots. The use rate by pilots is nearly 100 percent. The lap belts in all aircraft types were generally reliable with very few failures reported. A high percent (~65%) of the cases reported indicated that the lap belt prevented injuries. In only a few cases, was the lap belt reported to have produced injuries. The cases where the lap belt allowed injuries or produced are generally more frequent for the IT&TA crashes than for the T crashes. Few severe injuries were associated with the lap belt.

Table 56 – Efficacy of Lap Belts for Pilots

Aircraft	# Reported	Device Failed to Function	Device Prevented Injuries	Device Produced Injuries	# Severe Injuries
AH-1 T	28	0	20	1	3
AH-1 IT&TA	22	0	20	0	3
AH-64 T	36	0	23	0	0
AH-64 IT&TA	28	2	10	8	6
CH-47 T	10	0	8	2	1
CH-47 IT&TA	4	0	2	0	1
OH-6 T	5	0	3	0	0
OH-6 IT&TA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
OH-58AC T	63	0	47	1	2
OH-58AC IT&TA	25	0	14	2	0
OH-58D T	28	0	18	1	0
OH-58D IT&TA	8	2	5	2	1
UH-1 T	82	0	65	0	3
UH-1 IT&TA	47	2	29	1	6
UH-60 T	35	0	23	1	5
UH-60 IT&TA	13	0	7	0	4

In the cabin area, a lap belt was available in most all cases. However, the device was not used in a significant number of cases. Table 57 presents the number of times that the device was available and the number of times it was not used. The lap belt was least frequently used on the CH-47 and the UH-1. The

UH-1 also experienced a total of 7 functional failures of the lap belt. The UH-60 had 12 severe injuries associated with the lap belt. The frequency that the lap belt was reported to prevent injuries is lower for cabin personnel than for pilots. For the cabin personnel, fewer people experienced severe injuries in IT&TA crashes than in T crashes; this is a reversal from the experience of the pilots.

Table 57 – Efficacy of Lap Belts for Cabin Occupants

Aircraft	# Reported	Device Available	Device Not Used	Device Failed to Function	Device Prevented Injuries	Device Produced Injuries	# Severe Injuries
CH-47 T	14	14	9	0	4	0	2
CH-47 IT&TA	15	15	2	0	12	0	0
OH-58AC T	23	23	0	0	16	0	0
OH-58AC IT&TA	11	11	0	1	9	0	0
OH-58D T	6	5	0	0	5	1	0
OH-58D IT&TA	0	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
UH-1 T	91	91	8	0	48	3	5
UH-1 IT&TA	80	79	3	7	39	1	4
UH-60 T	42	39	9	2	18	2	12
UH-60 IT&TA	11	11	5	1	3	1	1

The shoulder harness shows a distinct trend of preventing fewer injuries in IT&TA crashes than in direct terrain crashes (Table 58). The AH-1 is the only aircraft where the shoulder harness performed equally well in both types of crashes. In the UH-60, the shoulder harness prevented injuries to pilots in only 27 percent of the reported IT&TA cases compared to 54 percent for the T crashes. Furthermore, the percent prevented in the UH-60 was distinctly lower than in the other aircraft. The UH-60 and the AH-64 both showed more cases of the shoulder harness-producing injuries. The UH-60 produced injuries in 11 percent of the reported T crashes and 20 percent of the IT&TA crashes. The shoulder harness produced injuries in 29 percent of the AH-64 IT&TA crashes. The AH-64 shoulder harnesses were also low in percentage of injuries prevented.

Table 58 – Efficacy of Shoulder Harnesses for Pilots

Aircraft	# Reported	Device Failed to Function	Device Prevented Injuries	Device Produced Injuries	# Severe Injuries
AH-1 T	28	0	20	2	3
AH-1 IT&TA	22	2	16	1	3
AH-64 T	39	0	24	3	0
AH-64 IT&TA	28	0	11	8	4
CH-47 T	10	0	8	2	1
CH-47 IT&TA	4	0	2	0	1
OH-6 T	5	0	3	0	0
OH-6 IT&TA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
OH-58AC T	64	0	51	0	3
OH-58AC IT&TA	25	0	14	2	0
OH-58D T	26	0	17	2	0
OH-58D IT&TA	13	4	6	2	2
UH-1 T	79	0	64	0	3
UH-1 IT&TA	46	0	28	2	6
UH-60 T	35	2	19	4	5
UH-60 IT&TA	15	1	4	3	5

For cabin occupants, there is a dramatic difference in the usage of shoulder harnesses between the observation aircraft and the cargo utility aircraft. In the case of the UH-1, shoulder harnesses were available in only a few cases. As displayed in Table 59, shoulder harnesses are reported available just six times in UH-1 T crashes, yet prevented five injuries. Likewise, shoulder harnesses were reported as being available in only three UH-1 IT&TA crashes, yet prevented three injuries. Although shoulder harnesses are available far more frequently in the UH-60 the usage rate is only about 50 percent. Where used, they prevented injuries 40 percent of the time in T crashes and 27 percent of the time in IT&TA crashes. With the exception of the OH-58AC, the shoulder harness data confirm a trend wherein the restraint systems are less effective in preventing injuries in the IT&TA crashes than in the T crashes. Two possible explanations are the differences in seat designs between the cockpit and the cabin or the greater variety of seat orientations in the cabin compared to a single orientation in the cockpit. Because shoulder harness usage is already low in the cabin, implementing a more complex harness system does not appear to be an appropriate solution.

Table 59 – Efficacy of Shoulder Harnesses for Cabin Occupants

Aircraft	# Reported	Device Available	Device Not Used	Device Failed to Function	Device Prevented Injuries	Device Produced Injuries	# Severe Injuries
CH-47 T	9	0	9	0	0	0	2
CH-47 IT&TA	2	2	2	0	0	0	2
OH-58AC T	22	21	1	0	15	0	0
OH-58AC IT&TA	10	10	0	1	8	0	0
OH-58D T	6	6	0	0	5	1	0
OH-58D IT&TA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
UH-1 T	64	6	49	0	5	0	4
UH-1 IT&TA	57	3	53	0	2	0	3
UH-60 T	40	34	20	1	8	3	11
UH-60 IT&TA	11	11	6	0	3	1	1

The performance of the inertia reel is expected to be closely allied with the performance of the shoulder harnesses. Looking at the number of injuries prevented as a percentage of the number reported there does appear to be a good correlation. Except for the two attack helicopters, the inertia reels prevent fewer injuries to pilots in IT&TA crashes than they prevent in T type crashes (as shown in Table 60). This result confirms the trend observed for shoulder harnesses. The exceptions to the trend are the two attack helicopters, where the percentage of prevented injuries is significantly higher for the IT&TA crashes.

Table 60 – Efficacy of Inertia Reels for Pilots

Aircraft	# Reported	Device Failed to Function	Device Prevented Injuries	Device Produced Injuries	# Severe Injuries
AH-1 T	28	1	18	3	3
AH-1 IT&TA	22	0	20	1	3
AH-64 T	36	0	21	0	0
AH-64 IT&TA	20	1	15	2	4
CH-47 T	10	0	9	1	1
CH-47 IT&TA	3	0	2	0	0
OH-6 T	5	0	2	0	0
OH-6 IT&TA	0	NO DATA	NO DATA	NO DATA	NO DATA
OH-58AC T	62	0	47	0	2
OH-58AC IT&TA	25	0	13	2	0
OH-58D T	25	1	18	1	0
OH-58D IT&TA	6	1	4	0	1
UH-1 T	78	0	59	0	3
UH-1 IT&TA	44	0	30	0	6
UH-60 T	38	2	18	1	7
UH-60 IT&TA	13	1	5	0	4

Inertia reels are not generally available in the cabin; and where they are available, they are seldom used (Table 61). The OH-58 and the UH-60 are the only two aircraft with inertia reels shown as being commonly available in the cabin. The inertia reel was used more often in the OH-58D T crashes, followed by the OH-58AC IT&TA crashes. For the UH-60 T crashes, inertia reels were reported available for 17 of 26 individuals, but were not used by 12 of those individuals. For the UH-60 IT&TA crashes, inertia reels were available to six of nine individuals, but were not used by all six. Where available, the inertia reel is credited with prevented some injuries, while producing zero injuries.

Table 61 – Efficacy of Inertia Reels for Cabin Occupants

Aircraft	# Reported	Device Available	Device Not Used	Device Failed to Function	Device Prevented Injuries	Device Produced Injuries	# Severe Injuries
CH-47 T	9	0	9	0	0	0	2
CH-47 IT&TA	2	1	2	0	0	0	0
OH-58AC T	21	15	6	1	11	0	0
OH-58AC IT&TA	10	8	2	0	7	0	0
OH-58D T	5	5	0	0	5	0	0
OH-58D IT&TA	0	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
UH-1 T	63	5	48	0	5	0	4
UH-1 IT&TA	57	2	54	0	2	0	3
UH-60 T	26	17	12	1	8	0	6
UH-60 IT&TA	9	6	6	0	1	0	1

The pilot seats show the same trend as the other protective devices. With the exception of the attack helicopters, the seats prevent fewer injuries in the IT&TA crashes than they do in the T crashes (Table 62). The number of injuries prevented by seats is relatively low being in the range of 50 percent and even lower for the OH-58D and the UH-60 for IT&TA crashes. In six AH-64 T crashes, the seat is reported to have produced injuries. Similarly, in five OH-58AC T crashes, in six UH-1 T crashes, and in four UH-60 T crashes, the seat produced injuries. Seats are reported to have failed to function in three OH-58AC T crashes, two UH-1 T crashes, and five UH-60 T and IT&TA crashes.

Table 62 – Efficacy of Pilot Seats

Aircraft	# Reported	Device Failed to Function	Device Prevented Injuries	Device Produced Injuries	# Severe Injuries
AH-1 T	28	0	18	6	3
AH-1 IT&TA	22	0	16	1	3
AH-64 T	35	0	19	2	1
AH-64 IT&TA	22	0	12	2	4
CH-47 T	8	0	6	1	1
CH-47 IT&TA	4	0	2	0	1
OH-6 T	5	0	0	2	0
OH-6 IT&TA	0	NO DATA	NO DATA	NO DATA	NO DATA
OH-58AC T	63	3	34	5	3
OH-58AC IT&TA	25	0	12	1	0
OH-58D T	24	0	12	1	0
OH-58D IT&TA	7	0	3	1	3
UH-1 T	79	0	53	6	3
UH-1 IT&TA	47	2	24	1	6
UH-60 T	35	5	16	4	5
UH-60 IT&TA	16	5	5	0	4

The data in Table 63 indicate that seats are widely available in the cabin and generally they are used. Six individuals in the CH-47 and nine in the UH-60 did not use seats. Four seat failures were reported in UH-1 cabins and six in UH-60 cabins. Seats were credited with preventing injuries between 40 and 80 percent of the time. Generally, the percentage of injuries prevented was higher for T crashes than for IT&TA crashes, except in the cases of the OH-58AC and the CH-47. The UH-1 seat was blamed for producing seven injuries in T type crashes.

Table 63 – Efficacy of Seats Cabin Occupants

Aircraft	# Reported	Device Available	Device Not Used	Device Failed to Function	Device Prevented Injuries	Device Produced Injuries	# Severe Injuries
CH-47 T	15	15	6	0	6	0	2
CH-47 IT&TA	15	15	1	0	13	0	0
OH-58AC T	22	22	0	0	13	2	0
OH-58AC IT&TA	11	11	0	0	7	0	0
OH-58D T	6	6	0	0	3	1	0
OH-58D IT&TA	0	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
UH-1 T	90	90	1	3	40	7	5
UH-1 IT&TA	81	81	1	1	32	0	4
UH-60 T	42	39	9	2	18	2	12
UH-60 IT&TA	19	19	1	4	7	1	3

Analyzing the protective equipment indicates that the IT&TA type crashes lead to injuries more frequently than the T type crashes. These data further indicate that the equipment designed to prevent injuries are less effective in the post-obstacle crashes.

3.9 – Analysis Using Severe Injuries as the Crash Outcome

One means of assessing the crashworthiness of an aircraft is to determine the impact conditions at which crashes become fatal to all persons on board. In an analysis on the crashworthiness performance of the UH-60, Dr. Dennis Shanahan[1] used data on the mortality rates in the UH-60 and the closest comparable aircraft the UH-1. Dr. Shanahan placed the vertical velocity for the crashes of each aircraft into increments (or bins) of 5 ft/s. He then plotted the average mortality rate for the crashes within each increment against the median velocity of that increment. In this analysis, the plots revealed distinct transitions in the mortality rate as a function of the vertical velocity. Furthermore, in comparing the plots for the UH-1 and the UH-60, the transition velocity for the UH-60 was higher than the transition velocity for the UH-1. Dr. Shanahan attributed this higher transition velocity to the superior crashworthiness designed into the UH-60. In modified form, this analysis approach developed by Dr. Shanahan is applied to the data in this study.

3.9.1 – Transition Velocity Analysis

The approach used in this study is simplified from the approach used by Dr. Shanahan. This study had access to two sets of injury data covering the same set of mishaps. The injury data in the INJURY_INFORMATION table contains more details about the injured personnel and the specific injuries and their causation. This table also contains information about the individual's role on the aircraft (i.e., pilot, crew member, or passenger). However, this table lacks information on people who were not injured. The injury data in the AIRCRAFT_INFORMATION table provides the number of people assigned to several categories of injury severity and whether the person was military or civilian. This table is more complete in providing a count of all the people in each crash, but lacks detail about the individuals. Members of the FSC team have expressed an interest knowing the variation in injury

severity between different roles on the aircraft. Initially, the analysis was conducted with the detailed injury data set. Once the data in the analysis had been reduced in order to create the charts, it was found that the number of fatalities was rather limited. Consequently, it was decided to increase the size of the data pool by including totally and partially disabling injuries. This decision is at least partially justified by the fact these types of injuries can have consequences for the military that are nearly as costly as a fatality in terms of lost mission capability and cost. Thus, in this analysis "severe injury" includes, fatality, missing, totally disabled or partially disabled. It was subsequently realized that the detailed injury data set contained insufficient crash numbers to define clear transitions. Consequently, the analysis was redone with the AIRCRAFT_INFORMATION injury data set.

In performing the analysis, two plots were created, one of the fraction of occupants severely injured plotted against the vertical speed of the aircraft at impact and the other plotted the fraction of severely injured against the ground speed of the aircraft. Note that these two speeds are irrespective of the attitude of the aircraft. On the plots, the T crashes were plotted as one set of data and the IT&TA crashes were plotted as a second set of data. Thus, differences in the transition velocities could be identified. As an example, the vertical speed plot for the AH-64 is presented (Figure 30). The transition velocity was determined by identifying the crash with the highest vertical velocity that had a fractional or zero value for fraction of personnel severely injured. This crash forms the lower boundary of the transition. Then, the crash with a fraction severely injured equal to one <u>and</u> the lowest vertical velocity just above the highest fractional crash velocity was selected as the upper boundary of the transition. These two velocities bracket the transition velocity as determined by the available data. If the two velocities were within 3 ft/s of each other, then the higher of the two velocities is reported in Table 64. If there is a wide gap between the velocities, then the range is reported.

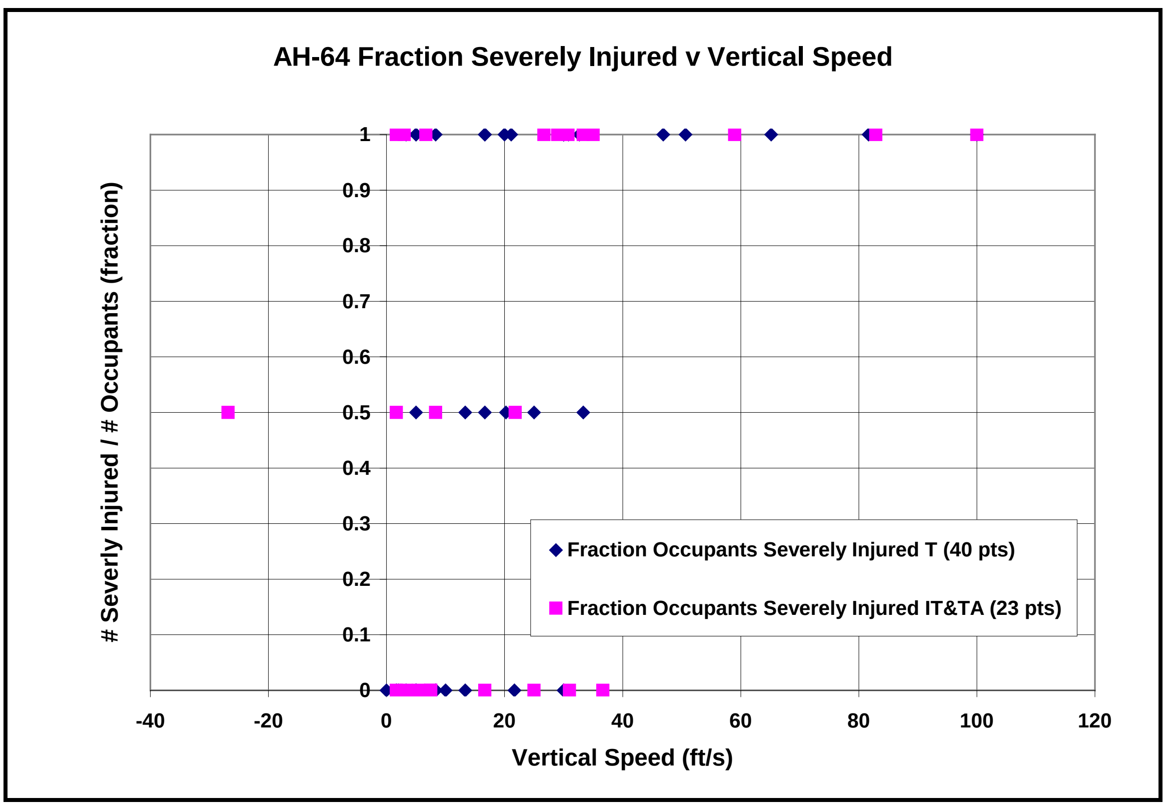

Figure 30 – AH-64 – Fraction Severely Injured Plotted against Vertical Speed

For the AH-64 T data, the crash with the highest fractional value has F_{SI}=0.5 and a vertical speed equal to 33 ft/s. It is difficult to see in the figure, but in the group of IT&TA data points just above this crash, there is a T data point also at 33 ft/s. Thus, the vertical transition speed for the AH-64 is determined to be 33 ft/s. For the IT&TA data, the highest fractional or zero value is F_{SI} = 0 at 37 ft/s and the crash with the lowest vertical velocity above that is 59 ft/s. Consequently, a range must be reported for the transition value. The velocity plots for all of the aircraft can be found in Appendix I.

Plots have also been created for the ground speed. However, the interpretation of these is somewhat problematic. As can be seen in Figure 31, there are partially survivable crashes at very high velocities. Using the same protocol as for the vertical speed, the ground speed transition for AH-64 T crashes is 202 ft/s and the ground speed transition for IT&TA crashes is greater than 84 and less than 101 ft/s. It is likely that the survivable crashes with very high ground speeds occur at low flight path angles on hard surfaces. Consequently, the resulting deceleration is over a long distance, which keeps the peak deceleration rate well below survivable levels for both the structure and the occupants.

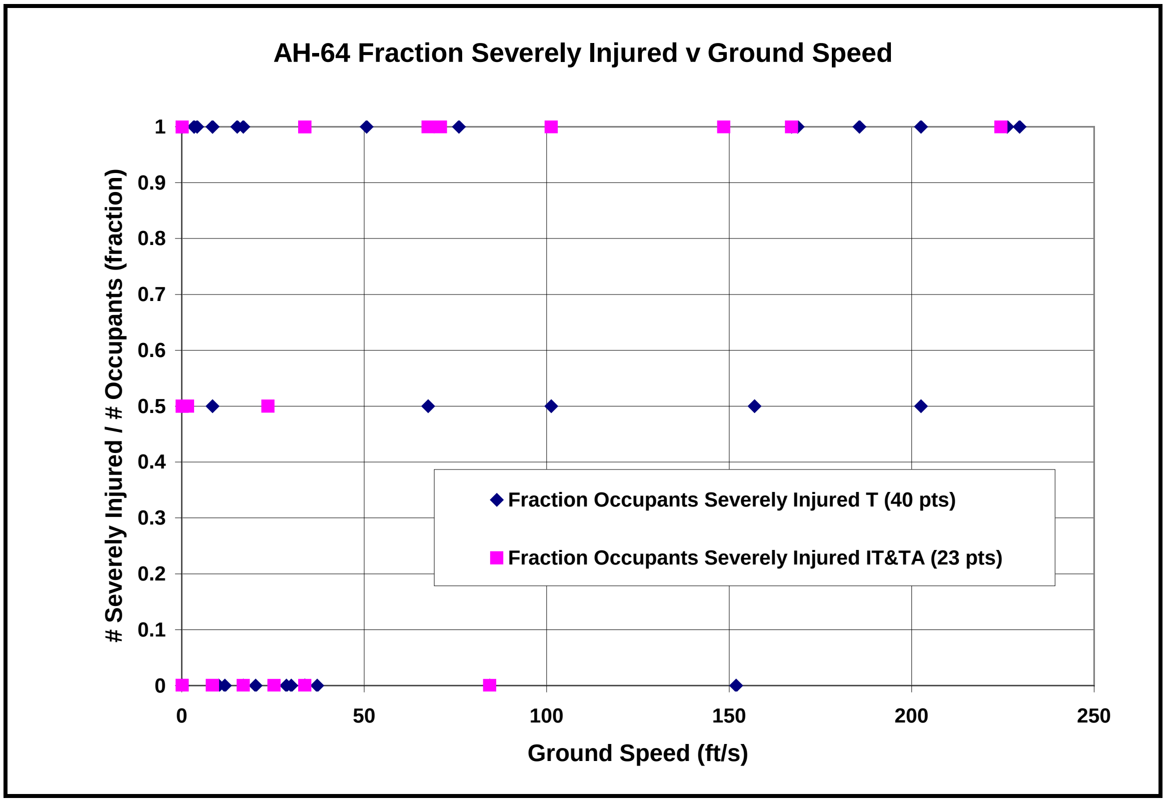

Figure 31 – AH-64 – Fraction Severely Injured Plotted against Ground Speed

Table 64 – Severe Injury Transition Velocities by Aircraft Type

Aircraft	# T Crashes	Transition Vertical Velocity T Est. (ft/s)	# IT&TA Crashes	Transition Vertical Velocity IT&TA Est. (ft/s)	Total Crashes
AH-1	12	>30	3	10<TV<13	15
AH-64	40	33	23	37<TV<59	63
CH-47	13	40<TV<50	0	No Est.	13
OH-6	3	TV>22	1	No Est.	4
OH-58AC	34	TV>42	13	23	47
OH-58D	32	28	12	13< TV<32	44
UH-1	31	30	7	33<TV<40	38
UH-60	25	50<TV<88	13	43	38

Looking for insight to extract from these injury transition velocities, the table can be regrouped by aircraft generation. Table 65 presents this regrouping. The first observation is that generally the T transition velocity is equal to or higher than the IT&TA transition velocity. This difference could be attributed to the expectation that pilot will have more control of the aircraft in the T crashes than in the IT&TA crashes. The inference may be taken a step further to suggest that the T transition velocities are indicative of the aircraft's overall survivability, that is, its autorotation characteristics plus structural and occupant crashworthiness. In contrast, the IT&TA transition velocity is indicative of the outcomes where the pilot is less of a factor. Therefore, these transition speeds reflect more of the structural crashworthiness only and less of the autorotation characteristics. This interpretation is perhaps most clearly supported by comparing the OH-58A/C transition velocity to the OH-58D transition velocity. Between these two aircraft, the primary difference is in the rotor system with the structure remaining highly similar. The data indicate that the D model has a distinctly lower transition velocity than does the A/C model for T crashes; however, the transitions for the IT&TA crashes are similar.

Table 65 – Severe Injury Transition for Vertical Velocity

Aircraft	Transition Vertical Velocity T Est. (ft/s)	Transition Vertical Velocity IT&TA Est. (ft/s)	Total Crashes
AH-1	>30	10<TV<13	15
OH-58AC	TV>42	23	47
UH-1	30	33<TV<40	38
AH-64	33	37<TV<59	63
OH-58D	28	13< TV<32	44
UH-60	50<TV<88	43	38

Comparing the AH-1 to the AH-64, little difference is observed for the T crashes. If indeed the decrease in transition speed associated with the rotor system as suggested by the OH-58 is true, then it may be argued that the decrease resulting from the difference in the rotor systems between the AH-1 and the

AH-64 was offset by greater structural and occupant crashworthiness in the A-64. The argument appears to be supported by the IT&TA transition velocities, where the AH-64 is dramatically better than the AH-1. A similar argument can be made for the utility helicopters. The UH-60 is dramatically better than the UH-1 for the T crashes, which supports the first part of the argument, and the UH-60 has a higher transition for the IT&TA crashes.

3.10 – Regression Analysis

In regression analysis, several variables are identified as candidates that may control the value of an outcome parameter. The outcome parameter is referred to as the "dependent variable" or the "response variable" because it depends on the values of the other variables. The controlling variables are referred to as "independent variables" or "regressor variables," because their values can be changed freely. The analysis tests the significance of each independent variable's contribution to value of the dependent variable.

Variables that are found to NOT actually affect or control the value of the dependent variable are said to be "not significant" and are systematically removed from the model. The result is a model in the form of an equation consisting of a coefficient for each "significant" variable multiplied times that variable. The analysis conducted has been a linear regression so each term is a coefficient times the corresponding variable to the first power. There is also one constant value determined.

Thus, a simple model for the fraction of severe injuries consisting of two variables, vertical speed, and ground speed, will look like:

$$F_{SI} = c_1 \text{*(vertical speed)} + c_2 \text{*(ground speed)} + k$$

The regression model provides values for the coefficients c_1 and c_2 and the constant k. Values for the vertical speed and ground speed of a crash can be inserted into this equation to predict the average value for the fraction of severe injuries in such a crash.

For this crashworthiness study, one outcome variable for which values are available is the number of personnel experiencing severe injuries in each crash. However, in order to be able to use data from a range of aircraft types, the number of severely injured personnel is normalized by the number of people reported to be aboard each aircraft. Thus, the dependent variable is the fraction of severely injured personnel [(number of fatalities + number missing + number totally disabled + number partially disabled) / (number onboard)]. By normalizing the number of injured personnel, data from attack helicopter crashes can be combined with and compared to data from helicopters with larger capacities, such as utility helicopters. The data available to this study include two sets of injury data. The set used here is from the AIRCRAFT_INFORMATION table and gives only a count of the number of each occupant type (military-civilian) with different severities of injury. These data were used because they were available for more crashes and appeared to more consistently include all the individuals aboard the aircraft, than did the detailed injury data. The detailed injury data is in the table identified as INJURY_INFORMATION.

The independent variables were divided into two groups: crash-related variables and aircraft design-related variables. The crash-related variables include: crash type, ground speed, vertical speed, aircraft attitude angles at impact pitch, roll, and yaw, impact surface, and MSL altitude. The aircraft design variables include the main rotor type, the number of rotor blades, the instantaneous disk loading, tail rotor position, and the landing gear type.

The crash variables are those that describe and quantify the crash intensity. The crash type is a two-level variable representing whether the crash was directly into the terrain (T), or a post-obstacle strike impact

into terrain (IT&TA). The type was coded CT=0 for T crashes and CT=1 for IT&TA crashes. The velocities in the Earth Reference Frame were used rather than the velocities in the Aircraft Reference Frame because the two velocities (ground speed and vertical speed) and the three attitude angles are the fundamental parameters reported by the investigation rather than being transformed data. Each of the three aircraft reference frame velocities contains all five of the fundamental parameters. The MSL altitude at emergency was used rather than the AGL altitude because the MSL altitude was reported for many more crashes than was the AGL. By using MSL rather than AGL, the analyses can be applied to a larger data set. The surface variable consists of six levels: prepared, ice, sod, snow, soggy, and water. These variables were coded prepared=1 through water=6. They were purposely coded in this order to reflect a progression from hardest to softest.

Variables that were not used include: terrain, terrain obstacles, impact severity (three axes, in G's), and altitude AGL. In each case, these variables were excluded because of the large number of missing data points. Regression works best when each data set (in this case, a crash) has a complete set of independent variable data points.

3.10.1 – Analysis of Crash Data by Aircraft Type

3.10.1.1 – OH-58A/C

The full model with all regressor variables and no interaction terms was fit initially. The p-value for the regression model being below 0.05 indicates that the regression model is significant (has one or more regressor variables that help explain the variation in the response variable). The individual p-values for the regressor variables are assessed, the variable with the highest p-value is removed from the model and the model is refit. This process continues until all the regressor variables that remain in the model are significant (i.e., have p-values ≤ 0.05). Figure 32 presents scatter plots with the fraction of personnel severely injured plotted on the vertical axes against each of the crash variables plotted on the horizontal axes.

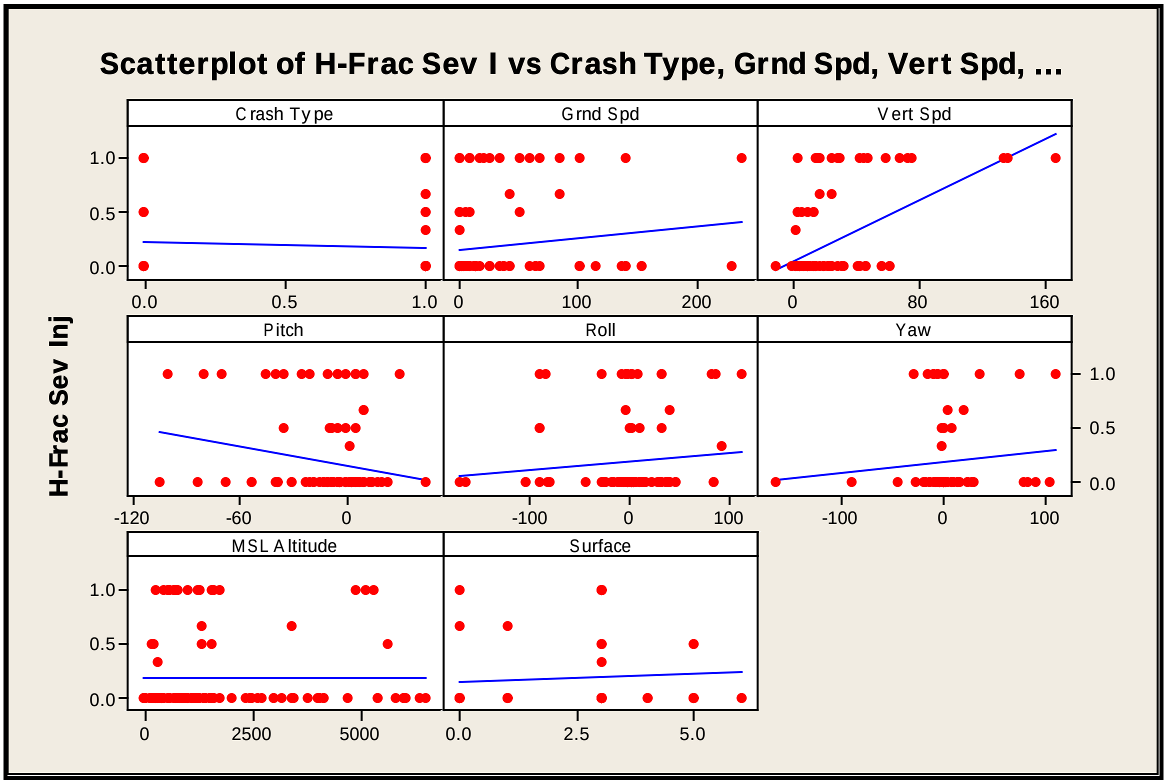

Figure 32 – OH-58A/C Crash Variable Scatter Plots

The resulting regression model indicates that the vertical speed and the roll angle have the greatest effect on the fraction of severely injured personnel. As vertical speed (VS) increases 1 ft/sec, the increase in mean fraction of severely injured people increases by 0.0074. For each degree increase in roll angle (RA), the mean fraction of severely injured increases by 0.0014. The values of the coefficients have been rounded off to two significant digits. The model equation is:

$$F_{SI} = 0.048 + 0.0074*(VS) + 0.0014*(RA).$$

Potential issues exist with several observations (i.e., crash cases) that are unusually influential in the model. However, if there is no practical reason for deleting these crash cases, then these cases should remain in the model. One method of eliminating these cases would be to review the crash data for each case not only for kinematic consistency, but for consistency with the performance of the aircraft and consistency between more of the variables. Such a detailed review was not within the scope of this effort.

The coefficient of multiple determination adjusted (R-Sq adj) is a statistic that reports what fraction of the variation in the dependent variable is accounted for in the regression model. The adjusted designation indicates that the statistic has been adjusted for the number of degrees of freedom in the model. For this model, adjusted coefficient of multiple determination is 29 percent. The low coefficient of multiple determination indicates that there are other regressor variables likely missing from the model that will explain more of the variation in the response variable. The final model only accounts for about 29 percent of the variation in the fraction of severely injured personnel. In a model to be used for predictive purposes, one would like to see at least 70 percent of the variation in the response variable explained by the model.

In an attempt to meet the statistical requirements for a sound model, several transformations of variables were tested. However, these variable transformations did not improve the coefficient of multiple determination nor the statistics indicating the quality of the assumptions. However, regression modeling is relatively robust against moderate departures from the assumptions and, consequently, limited conclusions can be drawn from these models.

The OH-58A/C crash data were also analyzed using the crash survivability parameter as the dependent variable. The survivability rating is assigned to the crash by the investigator. Survivability is a parameter coded with three discrete levels:

- S=1 for survivable,
- S=2 for partially survivable, and
- S=3 for non-survivable.

A "survivable" crash is potentially survivable at all occupant positions, a "partially survivable" crash is survivable for some occupant positions and a "non-survivable" crash is estimated to have no occupant positions meeting the criteria for survivability. To be considered survivable, an occupant position must have retained an open volume for the person to occupy and the position must have been subjected to no more than a humanly tolerable level of deceleration.

The regression model for crash survivability was run as an ordinal logistic regression. Background on this model type is provided here.

> **Background on Ordinal Logistic Regression**
>
> Logistic regression analysis is useful for describing the relationship between a categorical response variable and a categorical and/or continuous regressor (i.e., predictor) variables. Ordinal logistic regression is a special case that is useful when the response variable is ordinal (e.g., high, medium, low), as is the case with survivability. Survivability is ordinal with three values as described above.
>
> It is important to keep in mind that logistic models represent probabilities. That is, a logistic regression model describes a linear relationship between the logit, which is the log of the odds (probability based), and a set of predictor variables.

The results reported by Minitab in the "Logistic Regression Table" section of the ordinal logistic regression output summarize the predictor variable coefficients and the related odds ratio (OR) complete with a 95-percent confidence interval on the odds ratio. The interpretation is as follows:

- Positive coefficients with related OR >1 indicate that the higher predictor variable levels are associated with lower response variable levels. In this case, predictor variables with positive coefficients and OR >1 mean that as the predictor variable increases, the likelihood of a crash being survivable increases.

- Negative coefficients with related OR < 1 indicate that the higher predictor variable levels are associated with higher response variable levels. In this case, predictor variables with negative coefficients and OR < 1 mean that as the predictor variable increases, the likelihood of a crash being survivable decreases.

- Coefficient values close to zero (0) and OR ≅ 1 indicate the predictor has no significant effect on the response variable.

  In the ordinal logistic regression table describing each model, those predictor variables with p-values <0.05 are considered significant in that they significantly affect the probability of a crash being survivable, partially survivable, or non-survivable. The coefficient values can be interpreted as affecting the log odds. For example, a one-unit increase in a predictor variable will increase (for a positive coefficient) or decrease (for a negative coefficient) the log odds by the coefficient's magnitude listed in the table, given all other predictor variables are held constant. For example, when the variable for crash type increases by one unit (e.g., from 0 to 1 for a shift from an IT&TA crash to a T crash), the log odds for survivable versus partially survivable and non-survivable increase by the value of the coefficient in the model. For a continuous variable such as velocity, the log odds for the survivable crash increase by the model coefficient for each unit change in the variable (for each ft/s). Negative coefficients cause a decrease in the odds in a like fashion.

The regression model for crash survivability of the OH-58A/C was run as an ordinal logistic regression. The model includes 115 cases. The final model indicates that crash type, ground speed and vertical velocity significantly affect survivability.

The coefficients are presented. The coefficients predicted by the model for the two speeds are negative (Table 66) indicating that as either speed increases, the probability that the crash will be survivable decreases. The coefficient for the crash type is positive indicating that T type crash will have a greater probability of being survivable than an IT&TA crash.

Table 66 – OH-58A/C Ordinal Logistic Model Statistics

					Odds	95% CI	
Predictor	Coef	SE Coef	Z	P	Ratio	Lower	Upper
Const(1)	3.70179	0.771606	4.80	0.000			
Const(2)	5.32570	0.943297	5.65	0.000			
Crash Type	1.36615	0.669145	2.04	0.041	3.92	1.06	14.55
Grnd Spd	-0.0380213	0.0075529	-5.03	0.000	0.96	0.95	0.98
Vert Spd	-0.100861	0.0196418	-5.14	0.000	0.90	0.87	0.94

3.10.1.2 – OH-58D

The first regression model run on the OH-58D data uses the crash variables as the independent variables and the fraction of personnel severely injured as the independent variable. Figure 33 presents the fraction of severely injured plotted against each of the crash variables considered. The final fitted model includes only the vertical velocity. A model that includes the surface variable might be considered a better fit with the exception that the surface regressor variable has a p-value slightly above 0.05, the cut-off for

95 percent confidence. The model includes 44 cases and has an R-Sq(adj) value of 25 percent. The final model equation is:

$$F_{SI} = 0.161 + 0.019*(VS).$$

The OH-58D data were also analyzed using the survivability as the dependent variable and the ordinal logistic regression method. This analysis found none of the crash variables to be significant. Adding in the disk loading as a candidate variable did not result in a model with any significant variables.

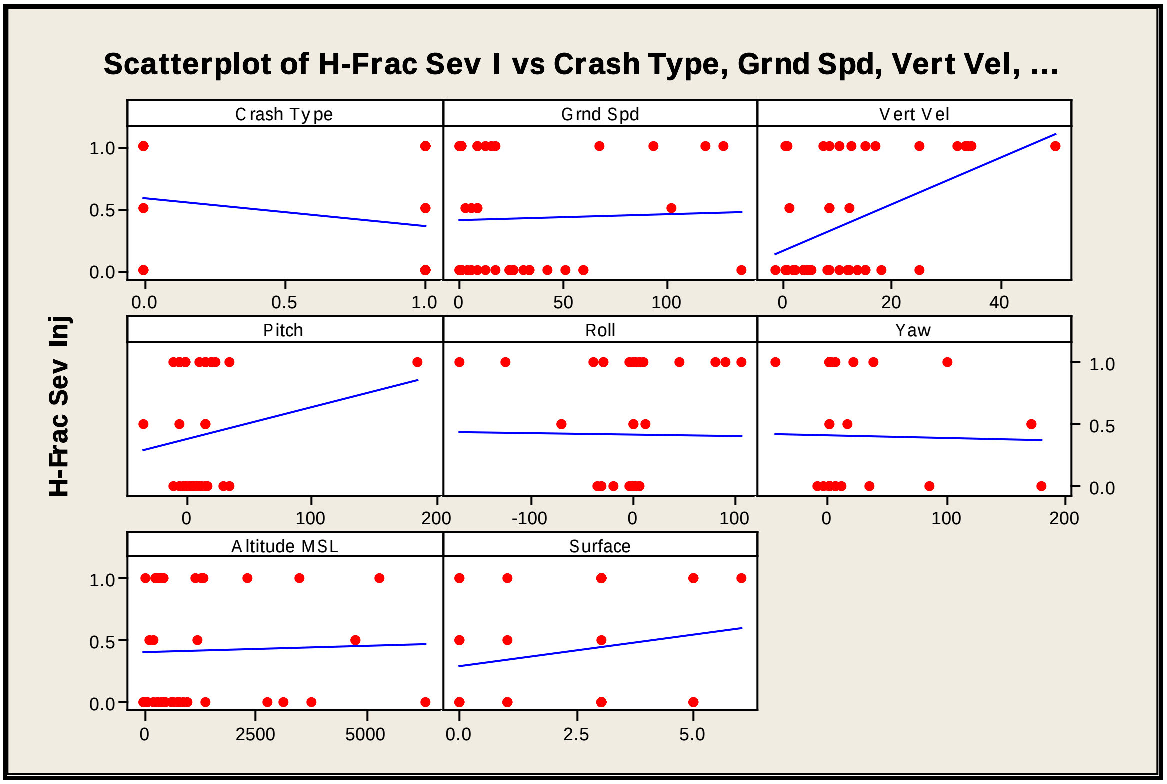

Figure 33 – OH-58D Crash Variable Scatter Plots

3.10.1.3 – AH-1

The first regression model attempted on the AH-1 uses only the crash-related variables. The dependent variable is the fraction of people on board who received disabling or fatal injuries. Scatter plots of the crash variable data for the AH-1 are shown in Figure 34. From this figure, one can discern the approximate trend between the dependent variable plotted on the vertical axes and the independent variable plotted along the horizontal axes.

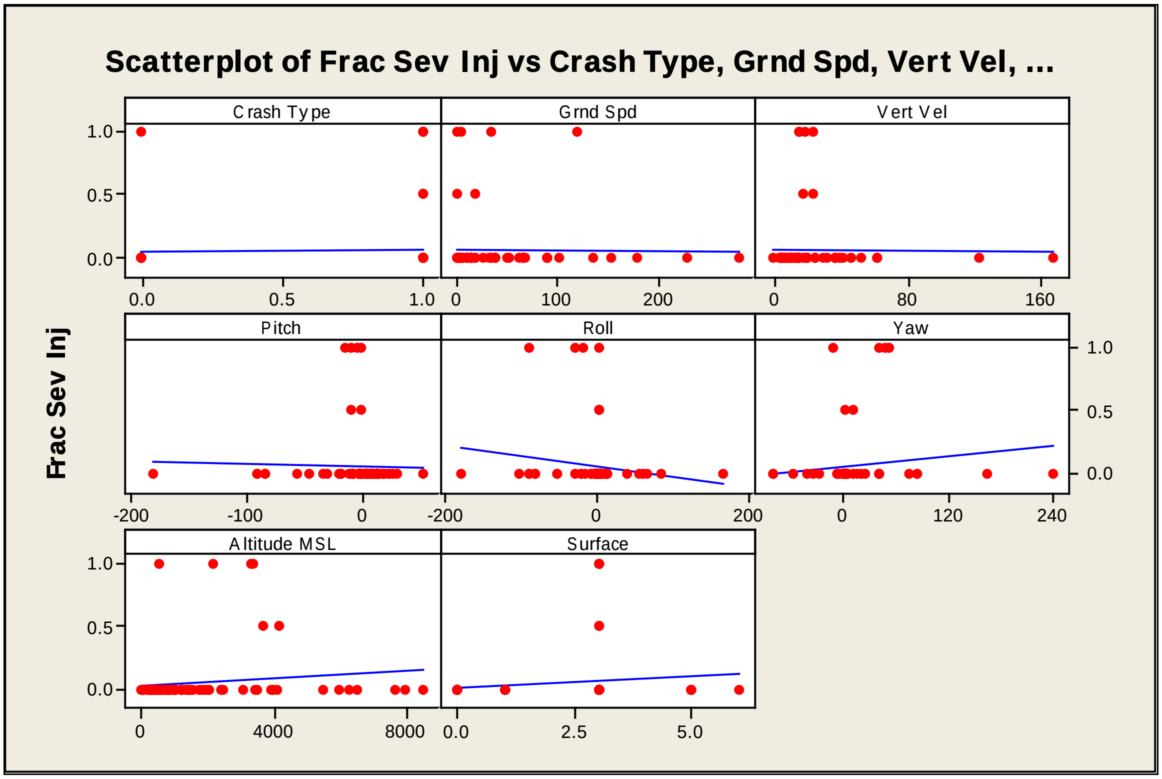

Figure 34 – AH-1 Crash Variable Scatter Plots

The analysis found none of the crash variables to be significant; consequently, there is no linear model generated for the AH-1.

The second AH-1 model attempted adds the aircraft variable of disk loading to the crash variables. The disk loading is found not to be a significant variable; consequently, there is no regression model of this type for the AH-1.

The third type of regression model attempted for the AH-1 uses the survivability rating as the dependent variable. The final logistic model indicates that for the AH-1, ground speed, vertical speed, crash type, and altitude MSL can be considered to significantly affect survivability an AH-1 crash. Table 67 reports the coefficients predicted by the model for the AH-1. The ground speed, vertical speed, and altitude MSL all have negative coefficients, indicating that as these parameters increase, the probability of a crash being survivable decreases. The effect of altitude MSL will be very small due to a small coefficient and an odds ratio equal to one. The coefficient for crash type is positive indicating that a T crash is more likely to be survivable than an IT&TA crash.

Adding the aircraft design variable disk loading to the logistic analysis on survivability finds that disk loading is not a significant variable in predicting survivability.

Table 67 – AH-1 Ordinal Logistic Model Statistics

					Odds	95% CI	
Predictor	Coef	SE Coef	Z	P	Ratio	Lower	Upper
Const(1)	3.36061	0.812857	4.13	0.000			
Const(2)	5.19234	1.02729	5.05	0.000			
Crash Type	1.71716	0.740668	2.32	0.020	5.57	1.30	23.78
Grnd Spd	-0.0155043	0.0070027	-2.21	0.027	0.98	0.97	1.00
Vert Vel	-0.111033	0.0238902	-4.65	0.000	0.89	0.85	0.94
Altitude MSL	-0.0003221	0.0001585	-2.03	0.042	1.00	1.00	1.00

3.10.1.4 – AH-64

The first regression analysis for the AH-64 includes only the crash variables. Figure 35 presents the scatter plot for each crash variable plotted with the fraction of severe injuries as the dependent variable. This model uses data from 58 crashes. After eliminating the non-significant variables, the equation calculated by the analysis for the final fitted model is:

$$F_{SI} = 0.060 + 0.0018*(GS) + 0.0078*(VS) + 0.079*(S)$$

Where GS is the ground speed in ft/s, VS is the vertical speed in ft/s, and S is a variable that describes the surface. The surface is a 6 level variable with the levels 1 to 6 coded for prepared surface (1), ice, sod, snow, soggy, water (6). While this is not a truly quantitative parameter, the surfaces were intentionally coded in order from firmest to softest in an attempt to identify a trend. The surface identified as “soggy” is coded equal to 5. According to the model, landing on a soggy surface will increase the predicted severe injury fraction by nearly 0.32 over the same crash on a prepared surface (1). Considering the limited range of injury fraction variable (0 to 1), 0.32 is a substantial influence.

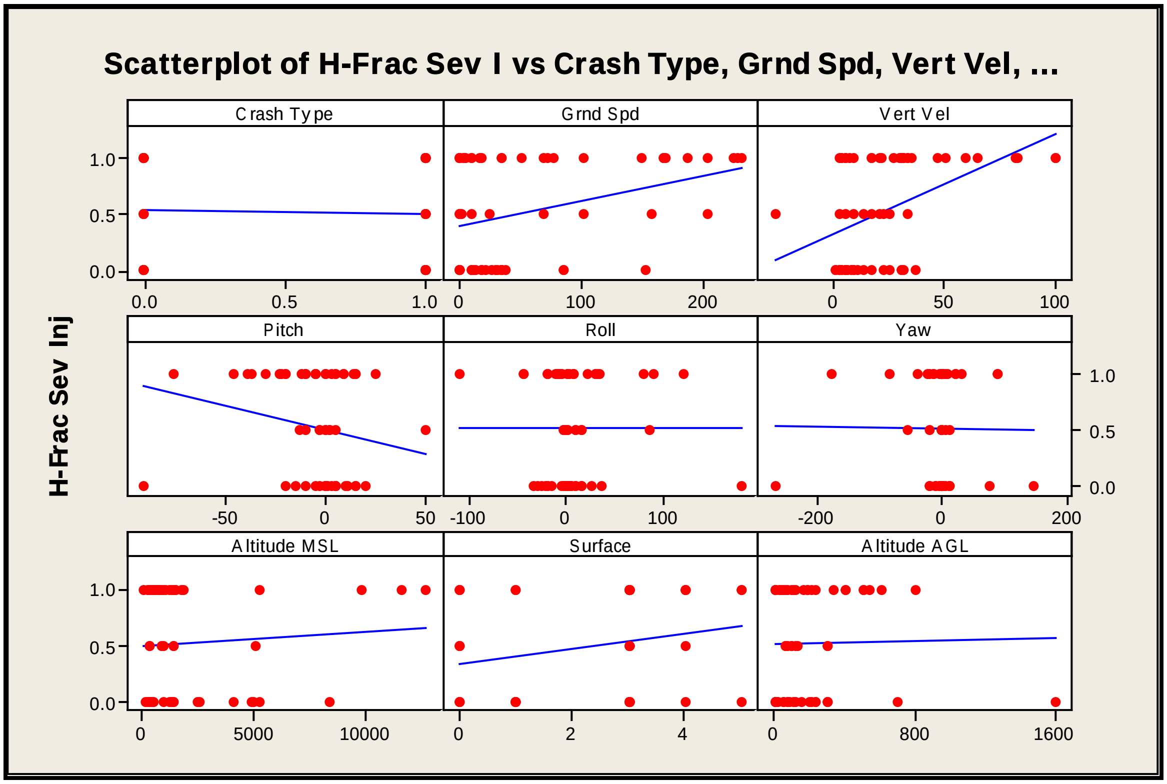

Figure 35 – AH-64 Crash Variable Scatter Plots

The statistic (p value = 0.61) indicating the significance of the constant value in the AH-64 model suggests that the constant is not significant and, thus, may be deleted from the equation. When this is done and the regression analysis rerun, the equation becomes:

$$F_{SI} = 0.0018*(GS) + 0.0082*(VS) + 0.094(S).$$

The same three variables are significant and retain approximately the same relationship to each other.

A statistic identified as R-Sq(adj) describes the amount of the variation in the dependent variable that the model explains. For this AH-64 model, the statistic is only 28 percent, indicating that this model accounts for only 28 percent of the variation in the dependent variable. Thus, the model has a very limited ability to predict the injury fraction of a crash given the values for these variables as input.

A linear regression model for the AH-64 fraction severely injured was also attempted with disk loading added to the crash variables. The analysis indicates that disk loading is not a significant variable in predicting the fraction severely injured in AH-64 crashes.

A logistic regression was conducted with the AH-64 crash variable data and survivability as the response variable. The final model indicates that the ground speed, vertical speed, crash type, and altitude MSL all are significant for survivability in AH-64 crashes. The coefficients for the ground speed, vertical speed, and altitude MSL are negative, indicating that the probability of a crash being survivable decreases as any one of these three variables increases. Although statistically significant, the effect of the altitude MSL

will be minimal. The crash type has a positive coefficient, indicating that a T crash has a higher probability of being survivable than an IT&TA crash.

Table 68 – AH-64 Ordinal Logistic Model Statistics

					Odds	95% CI	
Predictor	Coef	SE Coef	Z	P	Ratio	Lower	Upper
Const(1)	2.38233	0.692040	3.44	0.001			
Const(2)	4.49839	0.985226	4.57	0.000			
Crash Type	2.18504	0.860521	2.54	0.011	8.89	1.65	48.02
Grnd Spd	-0.0153011	0.0055335	-2.77	0.006	0.98	0.97	1.00
Vert Vel	-0.0641896	0.0177881	-3.61	0.000	0.94	0.91	0.97
Altitude MSL	-0.0002680	0.0001247	-2.15	0.032	1.00	1.00	1.00

3.10.1.5 – CH-47

The CH-47 is the one helicopter in the group that is of an entirely different configuration from the others. Rather than a single main rotor and single tail rotor that serves exclusively to control yaw, the CH-47 has two large main rotors and no yaw control rotor. The first regression analysis of the CH-47 is applied to the crash variables using the fraction of severe injuries as the dependent variable. Figure 36 presents the scatter plots of the dependent variable plotted against each of the independent variables. This model contains only 13 cases. An additional 11 cases had missing values.

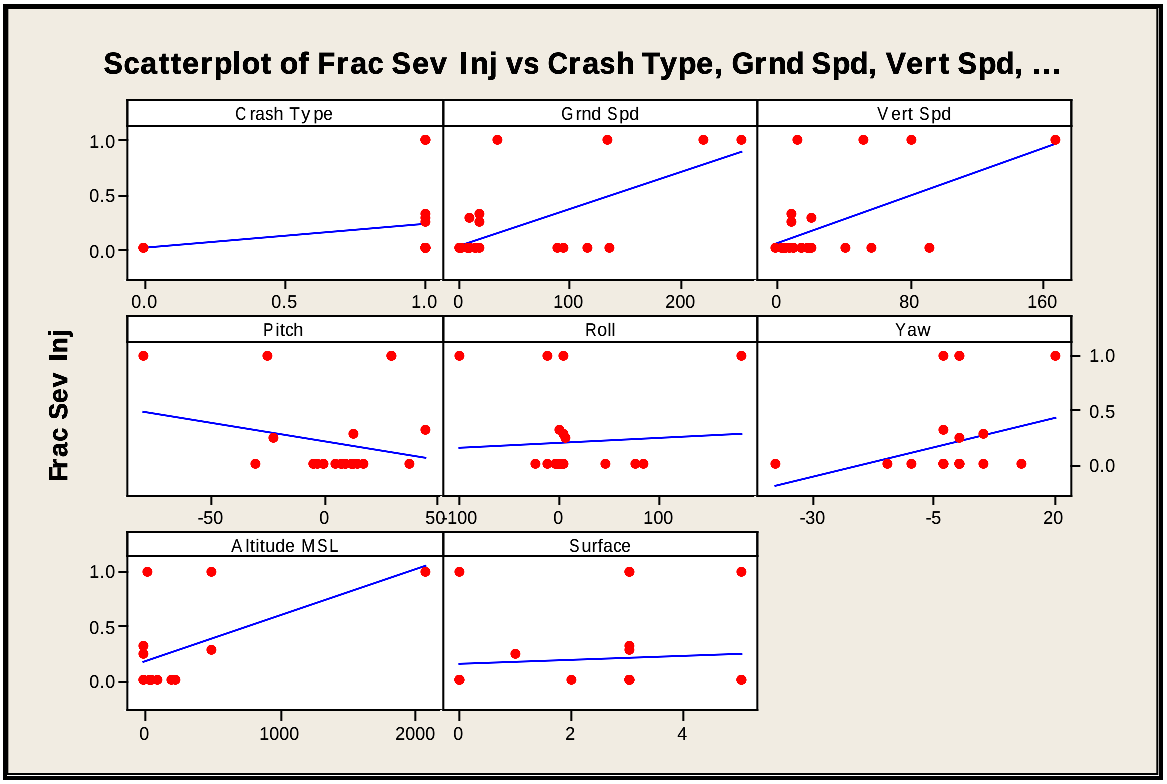

Figure 36 – CH-47 Crash Variable Scatter Plots

The significant crash regressor variables for the CH-47 are ground speed and vertical speed. The full model has an R-Sq(adj) value of 51 percent. The model equation determined by the analysis is:

$$F_{SI} = -0.035 + 0.0027*(GS) + 0.0037*(VS).$$

A second model was tried with the disk loading as an additional variable. The disk loading had a p value of 0.096 indicating that the variable was not significant. Furthermore, the inclusion of disk loading reduced the R-Sq (adj) value to 45 percent from 51 percent.

An ordinal logistic regression model was also attempted on the CH-47 data with the survivability as the dependent variable. However, the model failed to converge in 10,000 iterations and was terminated. No crash variables were found to be significant.

3.10.1.6 – OH-6

The OH-6 data were limited. No regression analyses were attempted using the crash data for this aircraft type. The OH-6 data were included when the regression analysis was carried out on the data for all of the aircraft types combined.

3.10.1.7 – UH-1

The first analysis carried out on the UH-1 data used the fraction of severely injured personnel as the dependent variable and the crash variables as the independent variables. The model includes data from 152 crashes. The scatter plots of the dependent variable plotted against the various crash variables are

shown in Figure 37. The model revealed that the vertical speed, ground speed, and crash type (CT) are significant in determining the value for the fraction severely injured. The R-Sq(adj) value is very low for this model at 14 percent. The model has very little predictive value other than identifying the significant variables. The model equation is:

$$F_{SI} = -0.098 + 0.0017*(GS) + 0.0043*(VS) + 0.12*(CT)$$

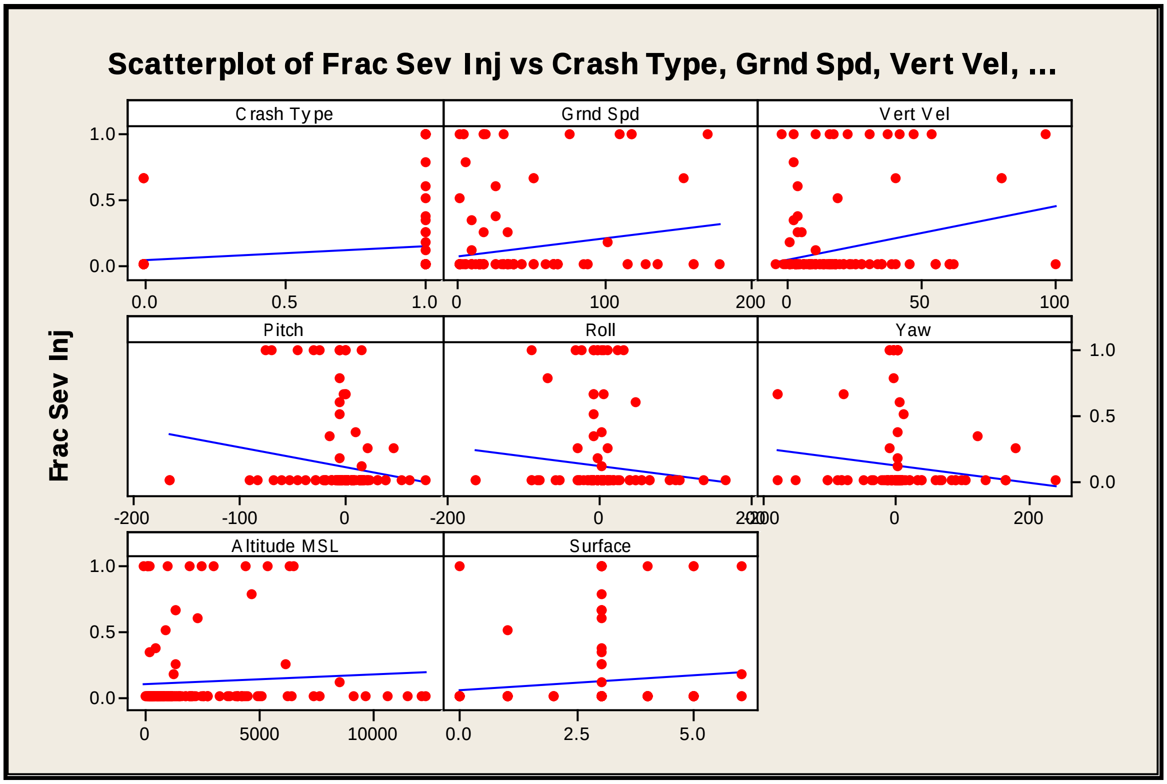

Figure 37 – UH-1 Crash Data Scatter Plots

This model for the UH-1 is the first linear regression model to find the crash type to be a significant variable. The crash type is coded 1 for a crash directly into to terrain and 0 for a crash following an impact with an inflight obstacle. The crash type term in the model equation thus takes on just two values: 0 or 0.12. The model predicts that a crash that follows an inflight obstacle will have an average of 0.12 higher fraction severely injured than a crash with the same velocity components directly into the terrain.

Adding the disk loading data to this basic regression analysis does not change the model. The disk loading is found not to be a significant variable.

The survivability was explored as an alternative dependent variable for the UH-1. For this analysis, 149 crashes were usable. This analysis confirms that the vertical speed and the ground speed were significant variables in determining the outcome of a crash, but it does not confirm the crash type as a significant variable. Both the ground speed and the vertical speed have negative coefficients, indicating that as these parameters increase, the probability of the crash being survivable decreases.

Adding the disk loading to the analysis of the original list of crash variables reveals that the disk loading is not significant for the survivability of UH-1 crashes.

Table 69 – UH-1 Ordinal Logistic Model Statistics

					Odds	95% CI	
Predictor	Coef	SE Coef	Z	P	Ratio	Lower	Upper
Const(1)	4.50562	0.592376	7.61	0.000			
Const(2)	6.37628	0.799865	7.97	0.000			
Grnd Spd	-0.0366466	0.0062998	-5.82	0.000	0.96	0.95	0.98
Vert Vel	-0.116200	0.0174139	-6.67	0.000	0.89	0.86	0.92

3.10.1.8 – UH-60

As with the other aircraft, the first regression attempted on the UH-60 data is the basic linear regression with the crash parameter data as the independent variables and the fraction severely injured as the dependent variable. Figure 38 presents the fraction of severely injured plotted against each of the crash variables. There are 61 crashes with complete data sets in this analysis. The only variable with statistical significance for the UH-60 is the ground speed. However, the next-to-last intermediate model actually has better overall statistics; this model retains three variables—vertical speed, ground speed, and pitch angle.

The last intermediate model was the one selected. The model equation produced by the analysis is:

$$F_{SI} = 0.331 + 0.0028*(GS) – 0.0037*(VS) – 0.0030*(PA).$$

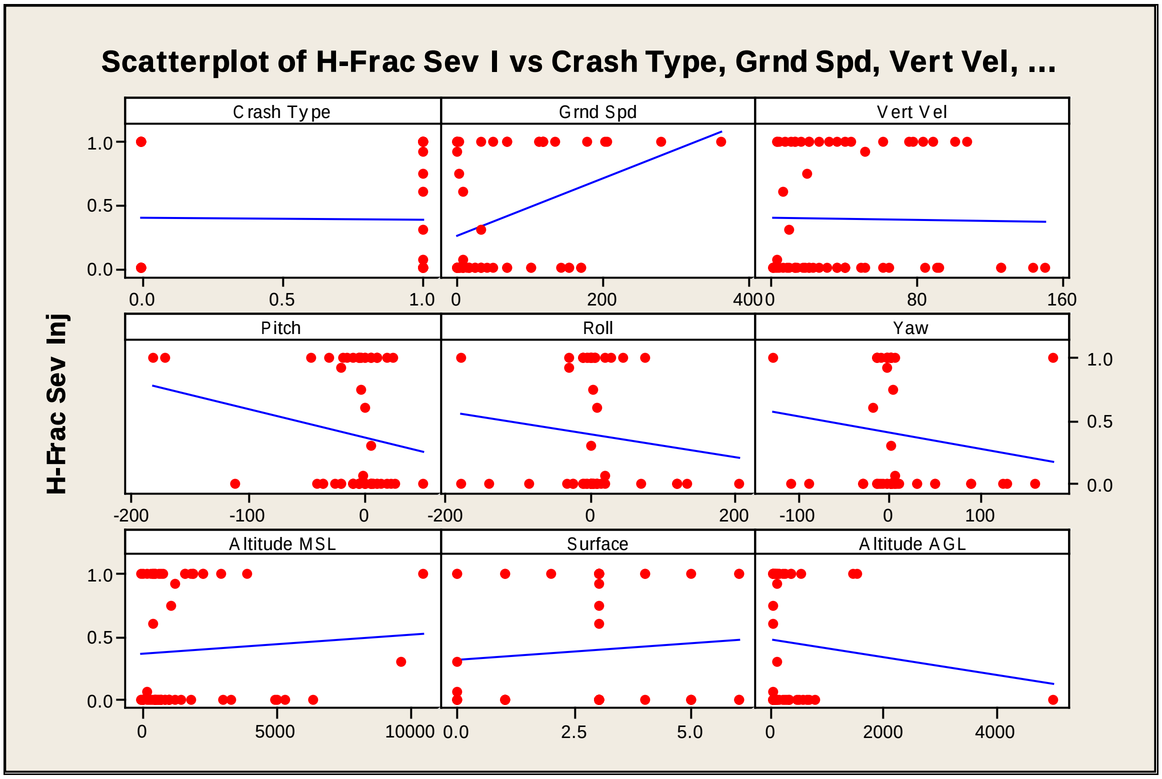

Figure 38 – UH-60 Crash Data Scatter Plots

Keeping the significant crash variables and adding the disk loading data to rerun the analysis, the regression finds that the disk loading is a significant variable for the outcome of UH-60 crashes. The equation of this model is:

$$F_{SI} = 0.27 + 0.0026*(GS) - 0.0031*(VS) - 0.0029*(PA) + 0.092*(DL)$$

In this model, both the ground speed and the disk loading have positive coefficients meaning that as the value of that variable increases the dependent variable also increases. That the fraction severely injured will increase as the ground speed or the disk loading increase is not surprising. That the coefficient for the pitch angle is negative indicates that the higher the nose at the moment of impact, the lower the resulting fraction of personnel severely injured. This prediction seems reasonable for all but very large positive pitch angles. That the vertical speed should have a negative coefficient seems counter-intuitive and is counter to the predictions made by several other models.

Because the negative coefficient for the vertical speed is unexpected and inconsistent with other models, some additional analysis was performed. The negative coefficient implied that as the vertical speed increases, the fraction severely injured slowly decreases. This can be seen in the scatter plot for UH-60 vertical speed in Figure 38. One can also see the same plot that his negative slope is likely due to the three crashes at very high vertical speed for which the outcome was zero serious injuries. To test this hypothesis, these zero fraction injury points at high velocity (VS > 110 ft/s) were omitted from the data set and the analysis rerun. Figure 39 reveals that the slope of the vertical speed line does change from negative to positive. However, the result in the rerun analysis is not that the coefficient also turns positive, but that the vertical speed variable ceases to be significant. Eliminating these points reduced the

significant variables to ground speed and disk loading. There is no reason for eliminating these data points and not other data except that the result is closer to what was anticipated. Consequently, we can not justify eliminating these data points and thus revert to the previous model.

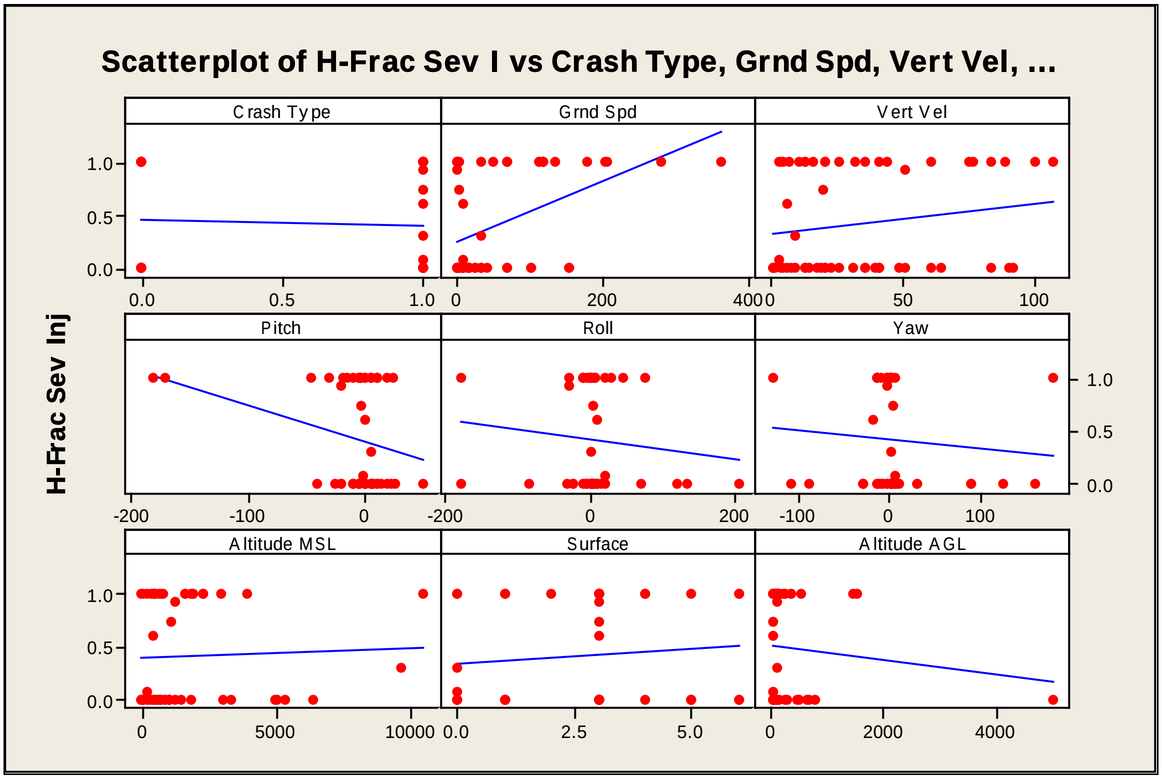

Figure 39 – UH-60 Scatter Plots for Revised Data Set

The UH-60 data were also analyzed using the survivability as the dependent variable and applying the ordinal logistic regression technique. In this analysis, 57 crashes had complete data sets. The final model finds ground speed and vertical speed to be significant variables. This result confirms the finding of the linear regression that the vertical speed is significant. Consistent with the other logistic models, the model for the UH-60 predicts negative coefficients for the vertical speed and the ground speed. No other regressor parameters were found significant for the UH-60.

Table 70 – UH-60 Ordinal Logistic Regression Statistics

					Odds	95% CI	
Predictor	Coef	SE Coef	Z	P	Ratio	Lower	Upper
Const(1)	2.43625	0.642240	3.79	0.000			
Const(2)	4.64016	0.914897	5.07	0.000			
Grnd Spd	-0.0231679	0.0066565	-3.48	0.001	0.98	0.96	0.99
Vert Vel	-0.0581866	0.0155497	-3.74	0.000	0.94	0.92	0.97

Testing Speed Squared as a Candidate Variable Using UH-60 Data

As a trial, the vertical speed squared and the ground speed squared were tested as candidate variables. The last two plots in Figure 40 present the scatter plots for these two added variables. It can be seen that the ground speed square has a strong positive slope and that the vertical speed has a weak negative slope. The best model of this group finds the ground speed, and vertical speed squared to be significant and the pitch to be just over the significance limit (p=0.05) with a value p=0.051. Retaining the pitch in this model improves the R-sq(adj) from 16.5 to 20.5; hence, this is the selected model. However, the coefficient has a negative sign rather than the expected positive sign. One would expect that the fraction of personnel severely injured would increase with increasing kinetic energy, which is proportional to velocity squared. As before, the negative slope may be driven by those few crashes with high vertical velocities, but in which there were no severe injuries. The equation for this model is:

$$F_{SI} = 0.282 + 0.0029*(GS) – 0.0032*(PA) – 0.000034*(VS)^2.$$

As one additional trial, the disk loading parameter was added to the regression of the crash variables. This analysis retained the three significant crash variables and found the disk loading to be significant too. The constant is no longer significant. The R-sq(adj) for this expanded model rose to 24.4, one of the higher values for the linear regression models in this study. The formula derived by this analysis is:

$$F_{SI} = 0.0027*(GS)^2 – 0.0032*(PA) – 0.000032*(VS)^2 + 0.0462*(DL).$$

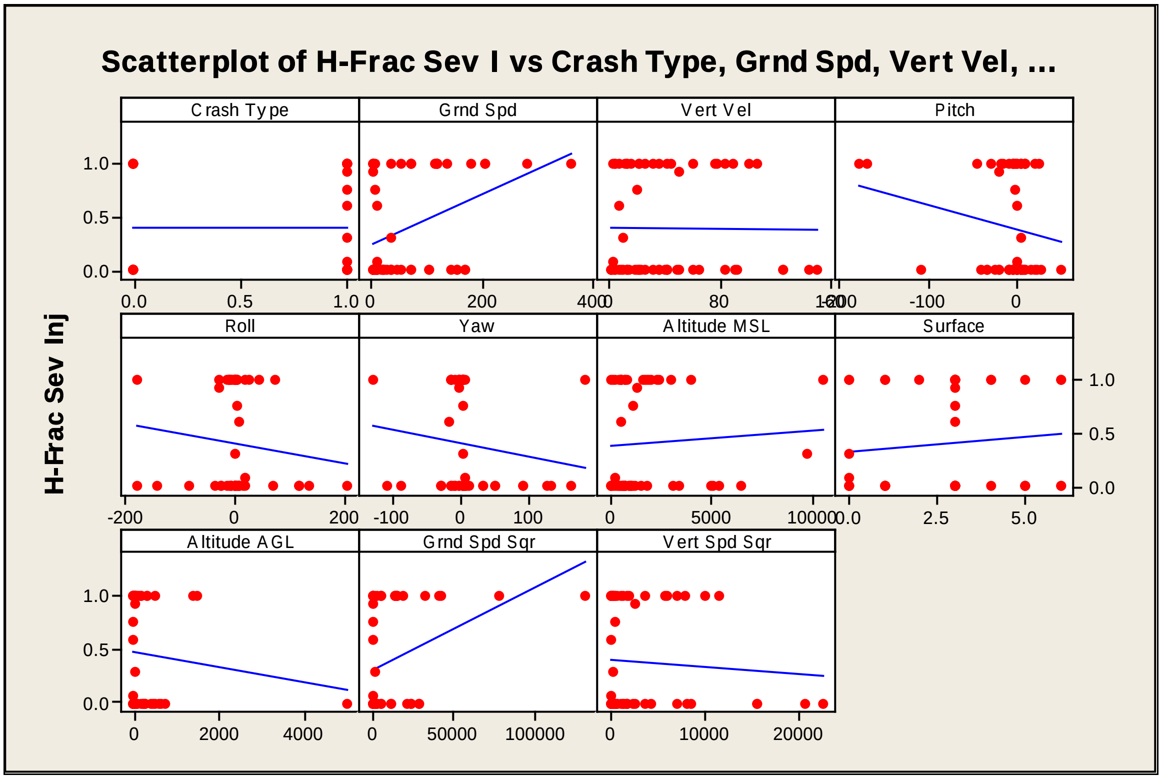

Figure 40 – Scatter Plots for Regression Analysis including Squared Speeds

3.10.2 – Summary Single Aircraft Linear Regression Analyses

Table 71 collects together the coefficients for each of the models. For the vertical velocity, the values range between 0.0037 and 0.019. These coefficients indicate that the OH-58D is five times more sensitive to each one ft/s increase in vertical velocity than are the UH-60 and the CH-47. It is somewhat surprising that the coefficients indicate that the 58D is 2.6 times more sensitive to a 1 ft/s increase in vertical velocity when compared to the 58A/C, which is structurally the same aircraft. The coefficients for ground speed are tightly clustered with a factor of only 1.6 separating the highest from the lowest. Also, the sensitivity in all cases is lower for the ground speed compared to the vertical speed. The lowest ground speed coefficient is only 75 percent of the highest vertical speed coefficient.

Table 71 – Linear Regression Model Coefficients

Aircraft	Vertical Speed	Ground Speed	Roll Angle	Pitch Angle	Surface	Crash Type	Disk Load.
OH-58A/C	.0074	-	.0014				
OH-58D	.019	-					
OH-6	No model						
AH-1	No model						
AH-64	.0082	.0018			.094		
CH-47	.0037	.0027					
UH-1	.0043	.0017				0.12	
UH-60	.0031	.0026		.0029			0.092

The linear regression analysis does confirm that vertical impact velocity is an important parameter in determining outcome. The vertical velocity was significant for every aircraft where a model was successfully generated. The ground speed of the crash was found to be significant on four of the eight aircraft types. However, the coefficients assigned to these parameters by the model indicate that the probability of severe injuries increases more slowly than might be expected as the speed increases. One would also have expected that the attitude angle at impact would be important, perhaps more so for those aircraft with energy absorbing landing gear. In fact, only the OH-58A/C has roll angle as significant. Additionally, the one other aircraft with a significant attitude angle is the UH-60 for pitch. Only one aircraft each were significant in the crash type and the surface. None of the other parameters was found to be significant, even for one aircraft type in the linear regression analysis.

The disk loading was added to the analysis of each aircraft type and proved NOT to be significant in all cases.

3.10.3 – Summary of the Single Aircraft Type Ordinal Logistic Regression Analyses

Table 72 summarizes the coefficients for all of the ordinal logistic models. Grouping the aircraft according to the design generation, a trend becomes apparent. For the vertical speed, the coefficients for the older-generation aircraft are almost twice as large as the coefficients for the second-generation aircraft. This means that the probability of a crash being survivable decreases almost twice as fast with each ft/s increase in vertical speed for the earlier generation aircraft compared to the later generation.

It is most unfortunate that the model for the OH-58D failed to find significant variables as the comparison between the two models might have revealed whether the difference was attributable to rotor system design or to other factors. There is no clear trend for the ground speed. While it is remarkable that the coefficient values for the OH-58A/C is almost identical to the value for the UH-1 and, likewise, the AH-1 is nearly identical to the AH-64, it is not clear that the similarity in these values is indicative of any underlying causality. It can be said that the survivability is much less sensitive to increment of ground speed than to each increment of vertical speed—in fact, roughly one-third as sensitive.

Table 72 – Logistic Regression Coefficients

Aircraft	Vertical Speed	Ground Speed	MSL Altitude	Pitch Angle	Surface	Crash Type
OH-58AC	-0.10	-0.038				+1.4
AH-1	-0.11	-0.016	-0.00032			+1.7
UH-1	-0.12	-0.037				
AH-64	-0.064	-0.015	-0.00027			+2.2
UH-60	-0.058	-0.023				
OH-58D	No sig. var.					
OH-6	No analysis					
CH-47	No model					

Notes: a. The CH-47 ordinal logistic regression model did not converge. No significance noted.
b. The OH-58D ordinal logistic regression model showed no significant crash variables.
c. The AH-64 Altitude MSL's coefficient is close to zero and the odds ratio is one; therefore, it really has minimal affect on survivability and could easily be deleted from the table above.
d. The OH-6 was not analyzed due to insufficient data.

3.10.4 – Regression – Aircraft Comparisons

3.10.4.1 – OH-58A/C Comparison with OH-58D

The OH-58 presents an opportunity for exploring the effect of one major design change to an aircraft. The OH-58A and C models have a rotor system design, which is characteristic of the earlier generation of aircraft studied here, including the UH-1 and the AH-1. This rotor design is referred to here as the "teetering" system. The D model OH-58 was extensively redesigned to incorporate more powerful engines and an entirely new rotor design known as the "bearingless" system. This system is characteristic of the later generation of aircraft in this study as represented by the UH-60 and the AH-64. The landing gear of the D model also received modestly increased capability, although the system remained a skid design. Even with the increased capability, the D model landing gear is not as capable as the energy absorbing systems in the later aircraft generation. Thus, the OH-58 presents a unique opportunity to isolate the effect of rotor system design on the injury outcome or survivability of helicopter crashes.

In the single aircraft type regression models discussed above, separate regression models were developed for both the A/C models and the D model. The best models for the two aircraft came out slightly differently with the 58A/C regression model including roll angle and the 58D regression model including only the vertical velocity. These individual models cannot be easily compared because the models found different variables to be significant. Consequently, the analysis on the data for each model was rerun to

retain the same independent variables. Therefore, an equivalent A/C model was created with only the vertical speed as a variable. The two comparable models are:

58A/C $F_{SI} = 0.048 + 0.0070*(VS)$.

58D $F_{SI} = 0.161 + 0.019*(VS)$.

The A/C regression model accounts for 27 percent of the variability and the D regression model accounts for 25 percent of the variability. The constant in neither model is significant at the 95 percent confidence level although the constant for the D would be significant at the 90 percent confidence level. The coefficient for the vertical speed of the D is nearly three times greater than the coefficient for the A/C. This difference means that for the same incremental increase in the vertical speed, the effect on the fraction severely injured will be three times greater in a D crash than in an A/C crash. The design differences between the two aircraft do not appear adequate to explain this difference in the outcome when one considers that the vertical speed is an explicit term in each equation. One normally associates the teetering rotor system with greater ability to store energy for autorotation than the bearingless system. The expected result is autorotation landings with the teetering system that are characterized by lower vertical speeds than those achieved by an aircraft equipped with a bearingless rotor system. Yet these two models explicitly take any difference in landing speed into account separately from the rotor system. Consequently, it must be concluded that the teetering system confers some additional survival advantage in a crash beyond a lower vertical impact speed. The D model carries more mass and has a higher maximum gross weight capability than either the A or C aircraft, but it also has a landing gear with increased capability. Looking at the nature of the injuries experienced by the occupants does not offer any insight to the difference.

The OH-58AC data were used to test for an interaction effect between the vertical velocity and the impact surface. The interaction was not statistically significant. Likewise for the OH-58D, the interaction with the surface was found to be very weak. While including the surface improved the regression model by some statistics, it degraded the regression model by other statistics. Consequently, the regression models including the surface were not pursued. A linear regression model was not attempted on the combined data set for the two aircraft.

The combined data for all of the OH-58 crashes were tested using survivability as the dependent variable and the ordinal logistic regression technique. This analysis included the data for 157 crashes. The final regression model (Table 73) finds vertical speed, ground speed, crash type, and yaw angle to be significant variables in controlling the survivability of OH-58A/C and OH-58D crashes. The coefficients for the ground speed, vertical speed, and yaw angle are negative. The negative values indicate that each incremental increase in one of these parameters reduces the probability that a crash will be survivable. The coefficient for the yaw angle is quite small and it takes an approximately 2.5-degree increase in yaw to have the same effect as 1 ft/s of ground speed and almost 7 degrees of yaw to equal the same effect as a 1-ft/s increase in vertical speed.

Table 73 – OH-58 (All) Ordinal Logistic Model Statistics

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	Upper
Const(1)	2.86571	0.554583	5.17	0.000			
Const(2)	4.13800	0.643814	6.43	0.000			
Crash Type	1.36258	0.516283	2.64	0.008	3.91	1.42	10.75
Grnd Spd	-0.0286431	0.0054149	-5.29	0.000	0.97	0.96	0.98
Vert Spd	-0.0731880	0.0141199	-5.18	0.000	0.93	0.90	0.96
Yaw	-0.0116096	0.0055588	-2.09	0.037	0.99	0.98	1.00

Considering all of these OH-58 regression models tells us that the difference in the outcome of OH-58 crashes between the A/C models and the D models as measured, either by the fraction of personnel severely injured or by survivability, is not simply a matter of vertical impact speed. This parameter by itself can only account for about 27 percent of the variation dependent variables, according to the linear model. The logistic model of the combined data sets indicates ground speed and yaw are also important, but neither of these parameters was connected in an obvious way to the difference in the rotor system designs.

3.10.4.2 – Analysis of All Aircraft Data Combined

The first analysis will treat just the crash variable data using the fraction of personnel severely injured as the dependent variable. The objective is to identify which crash variables are important in determining the outcome of crashes across all aircraft types. Figure 41 presents the scatter plots of fraction severely injured plotted against each of the crash variables. The model equation predicted by the analysis is:

$$F_{SI} = 0.92 + 0.0037*(VS) + 0.0013*(GS).$$

This model has an R-Sq(adj) value of only 12 percent despite including so much data. It is interesting to note that the last variable dropped from the analysis, for lack of significance, was the surface ($p = 0.106$) rather than the pitch angle. This model is consistent with the single aircraft analyses in finding the vertical and ground speeds to be the most significant crash variables, but it has a low predictive value.

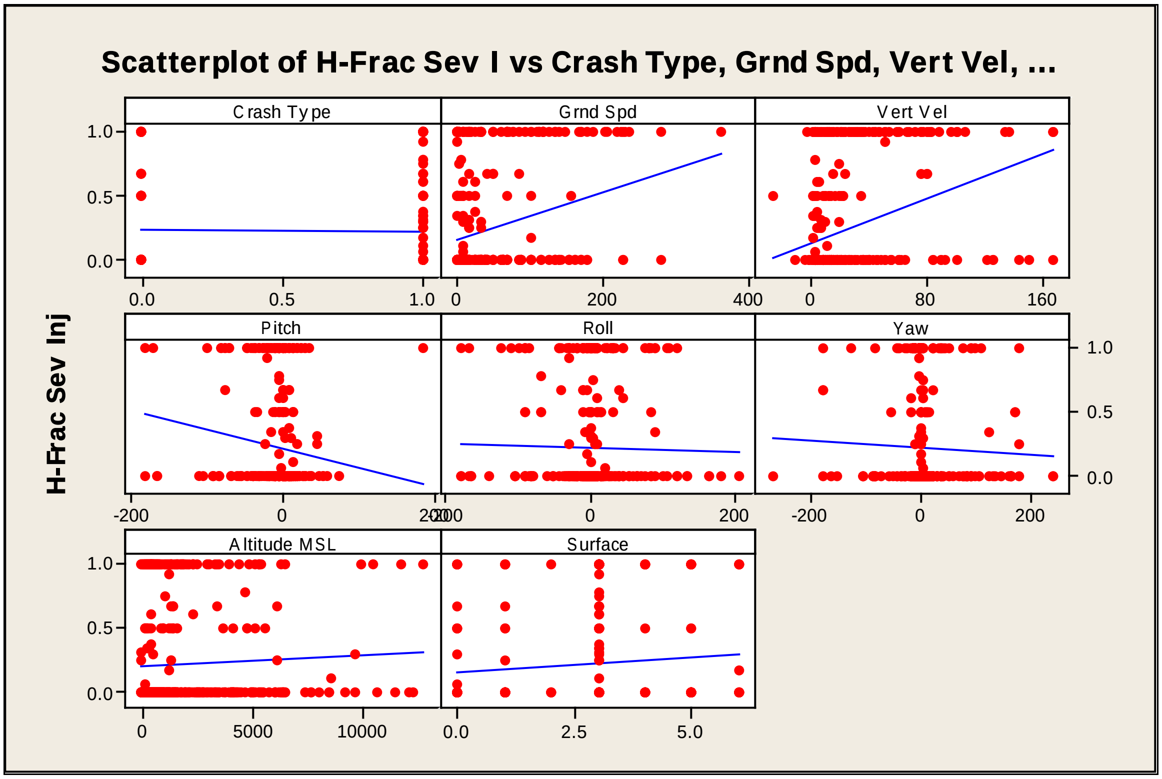

Figure 41 – All Aircraft Combined Crash Data Scatter Plots

In the second analysis on the all aircraft combined data, the data for the two significant crash parameters (ground and vertical speed) were retained and the aircraft design data were added. The five aircraft design variables are main rotor system type, number of main rotor blades, landing gear type, disk loading, and tail rotor position. The main rotor system was coded zero for bearingless and one for teetering. The main landing gear was coded zero for energy absorbing struts and one for skids. The tail rotor was coded zero for a high tail rotor position and one for a low tail rotor position. The number of rotor blades is self-evident and the disk loading is a continuous quantitative variable. Figure 42 presents the scatter plots for the two retained crash variables and for the five new aircraft design variables.

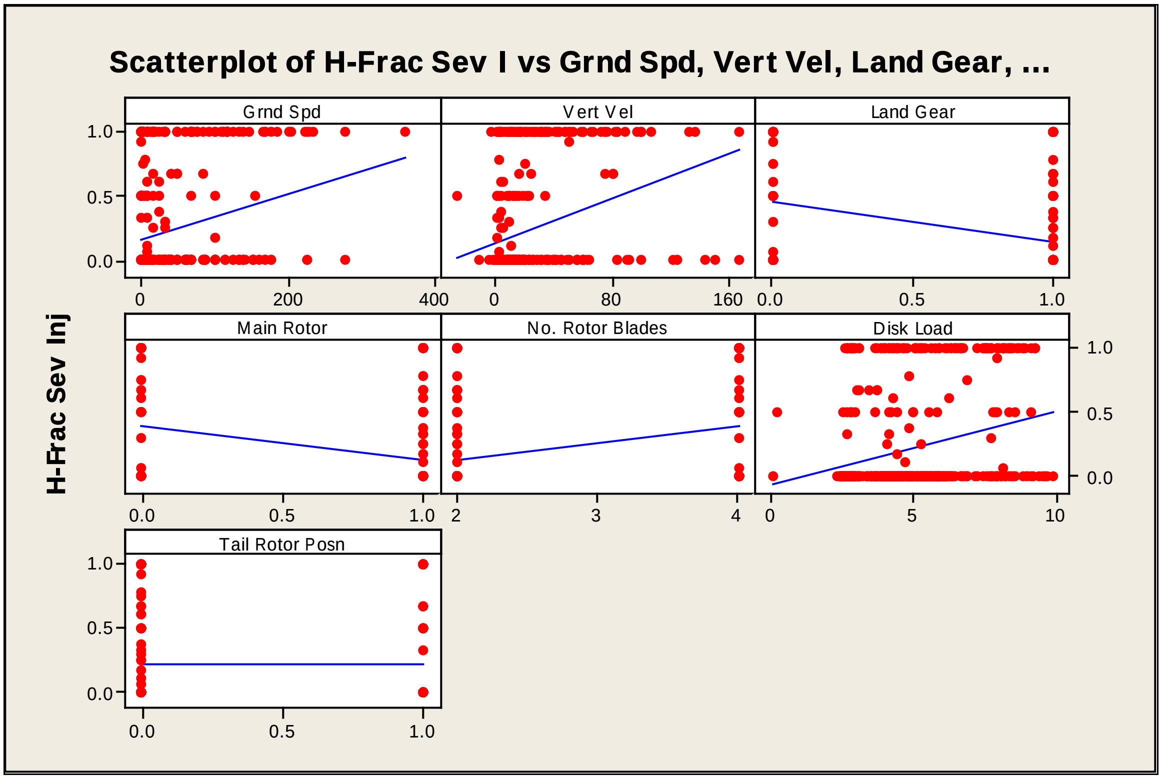

Figure 42 – All Aircraft Combined Crash & Aircraft Design Data Scatter Plots

In addition to ground speed and vertical speed remaining significant, the landing gear type, disk loading, and tail rotor position are all significant aircraft design variables. Despite the addition of three significant variables, the R-Sq(adj) statistic remains low at 20 percent. While this is an increase compared to the value obtained for the regression models, including only the crash variables, the statistic remains well below the values associated with useful predictive models. The model equation is:

$$F_{SI} = 0.082 + 0.0010*(GS) + 0.0032*(VS) – 0.16(LG) + 0.052*(DL) + 0.20*(TRP).$$

The intercept or constant value in the above equation is not significant (p=0.48). However, removing it decreases the quality of the model by certain other statistical measures yet does not significantly alter the values of the coefficients. Consequently, retaining the constant actually results in a slightly better model.

Using survivability at the three levels as the dependent variable and applying the ordinal logistic regression analysis confirms that the ground speed and vertical speed are significant independent variables. However, this analysis identifies pitch angle and crash type (terrain T or post-obstacle impact IT&TA) as being significant independent variables in determining the survivability. The model results are presented in Table 74. The ground speed and vertical speed have negative coefficients indicating that as the value for either of these parameters increases, the probability of a survivable crash decreases. The pitch and the crash type both have positive coefficients. Thus, positive increments of pitch result in more survivable crashes and a T crash is likely to be more survivable than an IT&TA crash.

Table 74 – All Aircraft Ordinal Regression Model Statistics

					Odds	95% CI	
Predictor	Coef	SE Coef	Z	P	Ratio	Lower	Upper
Const(1)	2.97497	0.281714	10.56	0.000			
Const(2)	4.61794	0.353023	13.08	0.000			
Crash Type	0.605333	0.252988	2.39	0.017	1.83	1.12	3.01
Grnd Spd	-0.0233972	0.0026072	-8.97	0.000	0.98	0.97	0.98
Vert Vel	-0.0731100	0.0071174	-10.27	0.000	0.93	0.92	0.94
Pitch	0.0140612	0.0041422	3.39	0.001	1.01	1.01	1.02

The logistic model for all aircraft combined confirms or consolidates the significance of the three most common variables for the single aircraft models: the crash type, ground speed and vertical speed. In the all aircraft analysis, pitch angle becomes significant whereas this parameter was not significant in any of the single aircraft models. Although identified as significant, the parameter has little predictive influence because its coefficient is small compared to the coefficients of the other three predictors.

3.10.5 – Discussion of Overall Regression Findings

The objective in performing a regression analysis is to create a predictive model for the phenomenon of interest. By establishing a quantitative relationship between the independent parameters and the dependent parameters, the model provides insight not only into causation, but also provides priority and quantitative predictions. Thus, when successful, regression analysis is very beneficial. The regression analysis conducted in this effort has not created models that can be relied upon for predictive purposes. A reliable model accounts for a substantial fraction of the variation in the dependent variable. As a rule of thumb, one would like to see at least 70 percent of that variation explainable by the model. Using the R-Sq(adj) statistic, the models created in this study account for less than 30 percent of the variability with the best accounting for just over 50 percent.

The statistical methods cannot explain why the technique does not work for a particular application. It is possible that the chosen dependent variables were not suitable. The outcome of direct concern is the number of personnel killed or severely injured in each crash. Consequently, the fraction of personnel severely injured was thought to be a good choice for dependent variable. This parameter still seems the best choice, despite the fact that it needed to be manipulated (i.e., normalized by the number of people on board, in order to be usable across all aircraft types). Even in this manipulated form, the value of the parameter is directly proportional to the acceptability of the outcome. One other dependent variable was used for analysis: the crash survivability rating. The challenge with this variable is that the three discrete levels associated with the outcomes do not have a proportional relationship. They are clearly ordered; entirely survivable is superior to partially survivable, which, in turn, is distinctly better than non-survivable. However, just one severely damaged occupant site changes a survivable crash into a partially survivable crash, even though there might have been a dozen survivable seat locations on the aircraft. Thus, the variable is only crudely indicative of the outcome.

It is very possible—in fact, the statistics suggest—that the data fields selected for analysis do not include all of the parameters needed to completely describe why personnel are severely injured in a particular crash. Thus, there may be parameters not included in this study that must be quite important. Unfortunately, whether these are parameters for which data are even being collected is not revealed by the analysis.

4.0 – CONCLUSIONS & RECOMMENDATIONS

4.1 – CONCLUSIONS

4.1.1 – Crashworthiness

Of the three operational phases reported in an accident sequence, the most common final operational phase reported is the Landing phase (49.6 percent), followed by Emergency Autorotation (24.9 percent). Training Autorotations are cited in 6.5 percent of the crashes. Crash is cited in only 9.7 percent of the events that this study has identified to be crashes. These surprising statistics may be attributed in part to the specific definition given for "Crash." A crash is defined to be the pilot retaining no control of the aircraft. The high percentage of events citing landing and either type of autorotation indicates that the pilots retained at least partial control of the aircraft, even though the outcome was measurable damage to the aircraft or injury to at least one occupant. This information suggests that designing helicopters to be crashworthy is justified on the basis that the pilot retains some ability to control the aircraft landing so as to maximize benefit from the crashworthy features of the aircraft

4.1.2 – Crash Type

This study divided the crashes into two types: crashes direct-to-terrain (T) and crashes into terrain following an impact with some obstacle above ground level (IT&TA, or "post-obstacle").

- Approximately 30 percent of all the crashes studied were post-obstacle crashes.
- The survivability of the two crash types differ: 73 percent of direct-to-terrain crashes are fully survivable (S=1), compared with 55 percent of the post-obstacle crashes.
- The AH-64 and the UH-60 experience a greater fraction (38 percent) of post-obstacle crashes than the earlier generation of attack and utility helicopters (31 percent). This comparison suggests that the trend is toward a greater frequency of post-obstacle crashes and thus, the 30 percent figure stated above is likely a low estimate for current and future activity.

4.1.3 – Kinematics

- The cumulative velocity curves recording ground speed (earth reference frame) are very similar for both direct-to-terrain crashes and post-obstacle crashes.
- The cumulative velocity curve recording vertical speed (earth reference frame) for the post-obstacle crashes is higher than the corresponding curve for direct-to-terrain at nearly all percentiles.
- As characterized by the 95th-percentile partially survivable crash, the vertical velocity (aircraft reference frame) for the direct-to-terrain crashes is very similar to that in the ACSDG'71[7] at 41 ft/s. The 95th-percentile for the post-obstacle crashes is slightly higher at 45 ft/s.
- The 95th-percentile longitudinal velocity (aircraft reference frame) for direct-to-terrain partially survivable crashes is 100 ft/s compared to 50 ft/s in the ACSDG'71[7]. The 95th-percentile longitudinal velocity for the post-obstacle crashes is lower at 80 ft/s.

- The 95th-percentile lateral velocity (aircraft reference frame) for direct-to-terrain partially survivable crashes determined in this study is 18 ft/s. No corresponding value was determined in the ACSDG'71[7] for comparison. The same parameter for post-obstacle crashes is 28 ft/s.
- Direct-to-terrain crashes occur more frequently with low flight path and low impact angle than do the post-obstacle crashes. In contrast, the post-obstacle crashes occur almost twice as often with near vertical flight path and impact angles.
- Consistent with previous studies the attitude angles of crashes directly into terrain are tightly clustered around the normal flight attitude (pitch, roll, and yaw = 0).
- The two crash types have different frequency distributions for the attitude angles. The post-obstacle crashes show lower peak frequencies at the zero values, broader distributions, and more extreme values. A regression analysis of the angle data confirmed the larger angle variation in the post-obstacle crashes.
- The mean impact severities for the post-obstacle crashes are equal to or higher than the mean impact severities for the direct-to-terrain crashes.
- Sixty-six percent of all crashes occurred on sod. Just 16 percent occurred on prepared surfaces. These relative frequencies remained consistent between both survivable and non-survivable crashes and between crashes directly to terrain and post-obstacle crashes.
- Trees are the most common obstacles associated with crashes. Trees are present in the vicinity of 40 percent of survivable and partially survivable crashes directly-to-terrain. They were present near 72 percent of the post-obstacle crashes. In the case of post-obstacle crashes, the presence of trees does not necessarily mean that the obstacles struck were actually trees.

4.1.4 – Other Considerations

- Crashworthy fuel systems have virtually eliminated deaths due to post-crash fires. Only two accidents occurred with multiple deaths due to post-crash fire and both involved non-crashworthy auxiliary fuel systems.
- Protective equipment, lap belts, shoulder harnesses, inertia reels, and seats are widely used by pilots and are generally effective. The same equipment is less available, less often used, and less effective (when used) for people in the cabin.

An analysis was conducted to identify the velocity at which the crashes by each aircraft type resulted in severe injuries (fatal or disabled) to all onboard. Above the severe injury transition velocity, all occupants experience severe injuries. The severe injury transition velocity can be interpreted as one measure of the crashworthiness of the aircraft.

- The vertical transition velocities for the direct-to-terrain crashes were generally higher than the transition velocities for the post-obstacles crashes of the same aircraft type. The UH-1 and AH-64 were exceptions.
- Grouping the aircraft by rotor system and looking at the vertical transition velocity reveals that the OH-58D with the bearingless rotor system has a much lower transition velocity than the OH-58A/C with a teetering rotor system (28 vs. >42 ft/s).
- The UH-60 has the highest vertical transition velocity in the analysis and, as such, could be considered the most crashworthy aircraft by this measure.
- Similar comparisons for the post-obstacle crashes reveal that the OH-58A/C and D have virtually identical transition velocities. This outcome suggests that the transition velocity for these crashes

has more to do with the structural integrity and personal protective equipment than the rotor system. This inference is supported by the fact that the transition velocity for the AH-64 is far higher than for the AH-1 and, likewise, the UH-60 is significantly higher than the UH-1.

4.1.5 – Accident Reporting and Data Recording

The mishap database maintained by the U.S. Army Combat Readiness Center is a valuable tool for crash analysis. Without the data recorded in this resource, identifying and justifying crashworthy technology would be an essentially subjective exercise. However, like all data, analysis often reveals two things: subtle flaws in the data and potential new data fields.

- Of the two altitude parameters recorded for each crash, ALTITUDE_MSL and ALTITUDE_AGL, the AGL parameter was far less frequently populated. However, between these two, the altitude AGL has greater significance to crashworthiness because it influences the pilot's time and potential energy for affecting a successful autorotation. The regression analysis indicated that ALTITUDE_MSL had only a very weak influence on the crash outcome.
- The direction reported for vertical impact forces was frequently inconsistent with the direction of the vertical velocity component. A review of the instructions to the investigator revealed that the definition of "upward" and "downward" acceleration are not clear.
- The values for impact forces up to approximately 30 G appeared to be reliable and consistent with the reported velocities. Values above 30 G did not correlate well with velocities. Several values were reported as 99 or 100 G. Several values were reported in excess of 100 G. When plotted with other impact force data, these values appear to be outliers. While these values are almost always associated with non-survivable accidents, a better means of determining the actual impact severity is desirable.
- Information on the number of people involved in the crash is documented in two different tables within the database. The table containing injury information does not record uninjured personnel. The aircraft information table reports the number of people in each of several injury severity categories including uninjured. However, there is not a field to record the total number of people on board the aircraft. The data for the number of fatalities and severe injuries recorded in the two tables are not consistent.

4.2 – Recommendations

Some of the findings in this report suggest that a fundamental re-evaluation of crashworthiness strategy should take place. The current strategy concentrates on vertical energy absorption. The findings in this study indicate that the strategy should be more robust to impacts that occur off the normal aircraft attitude. The fact that 30 percent of the crashes in this study were post-obstacle crashes and that these crashes have significantly lower survivability suggests that the aircraft crashworthiness is less effective in these events. That the post-obstacle crashes lead to greater variation in the impact attitude suggests that the crashworthiness mitigation technologies should be more robust to non-normal attitude angles. The fact that only 16 percent of crashes occur on prepared surfaces suggests that the mitigation technology should also be robust to variations in the surface stiffness. A shift toward greater design tolerance may lead to less reliance on landing gear for energy absorption with the weight being re-allocated to more robust structure and other means of absorbing energy that are more effective in the lateral directions and on softer surfaces.

The need to re-evaluate the approach to crashworthiness is supported by the fact that the current generation aircraft represented by the AH-64 and the UH-60 are experiencing post-obstacle crashes at a frequency of 38 percent, rather than the 30 percent for the whole study population of crashes.

4.2.1 – Accident Reporting and Data Recording

The following suggestions are offered in the spirit of improving the usability of the data reported and recorded in the database.

- Emphasize to investigators the importance of making an estimate of ALTITUDE_AGL particularly at the time of the emergency. Alternately, the inclusion of this parameter in a crash data recording device is very desirable.
- The instructions for reporting the aircraft impact severity (impact accelerations) should be clarified to reduce the inconsistency in the direction. There appears to be confusion between the terms “up” and “down” as applied to acceleration, possibly compounded by the use of the term “acceleration” for both acceleration and deceleration.
- The measurement of both direction and magnitude for impact severity by a crash data recorder is very desirable.
- Having a single field to report the total number of people on board the crashed aircraft would be very useful for analysis purposes.
- At the time of data entry, resolve discrepancies between the number of injured people recorded in the AIRCRAFT_INFORMATION table and the number of injured people recorded in the INJURY_INFORMATION table.

Appendix A – Cumulative Velocity Plots

Terrain Impacts (T, S=1&2)

Post-Obstacle Impacts (IT&TA, S=1&2)

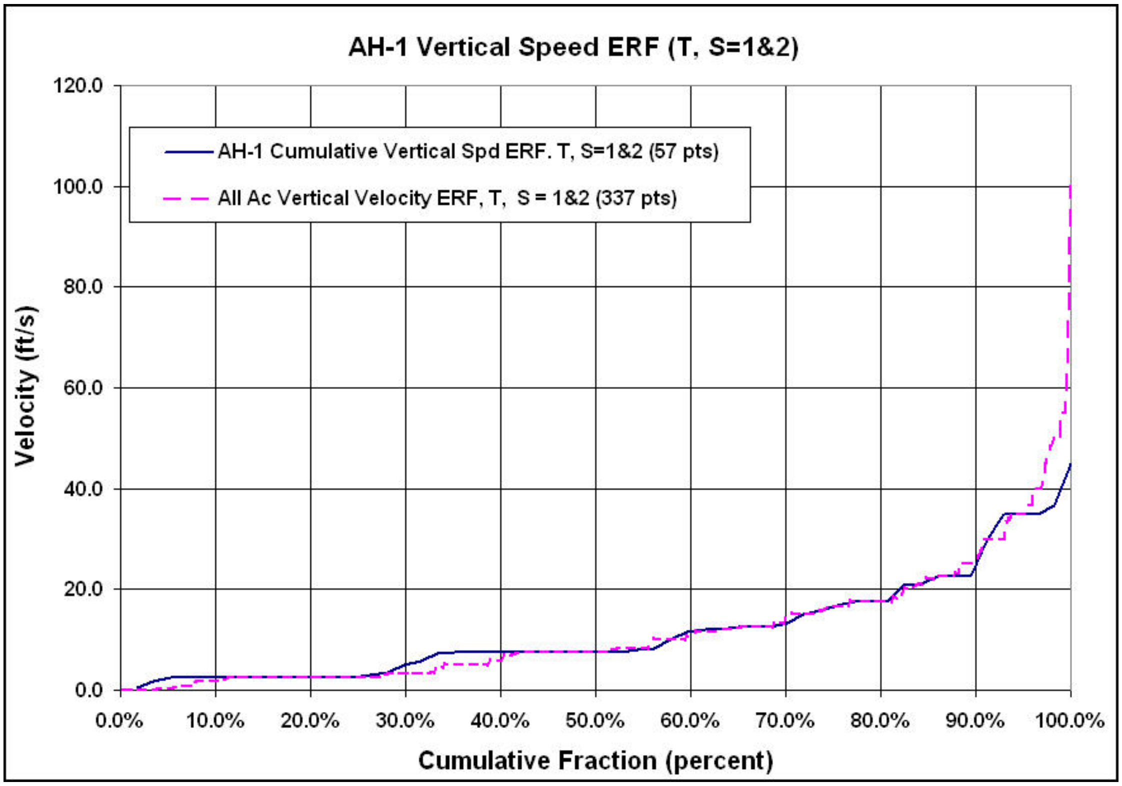

Figure A-1 – AH-1 Vertical Speed ERF (T, S=1&2)

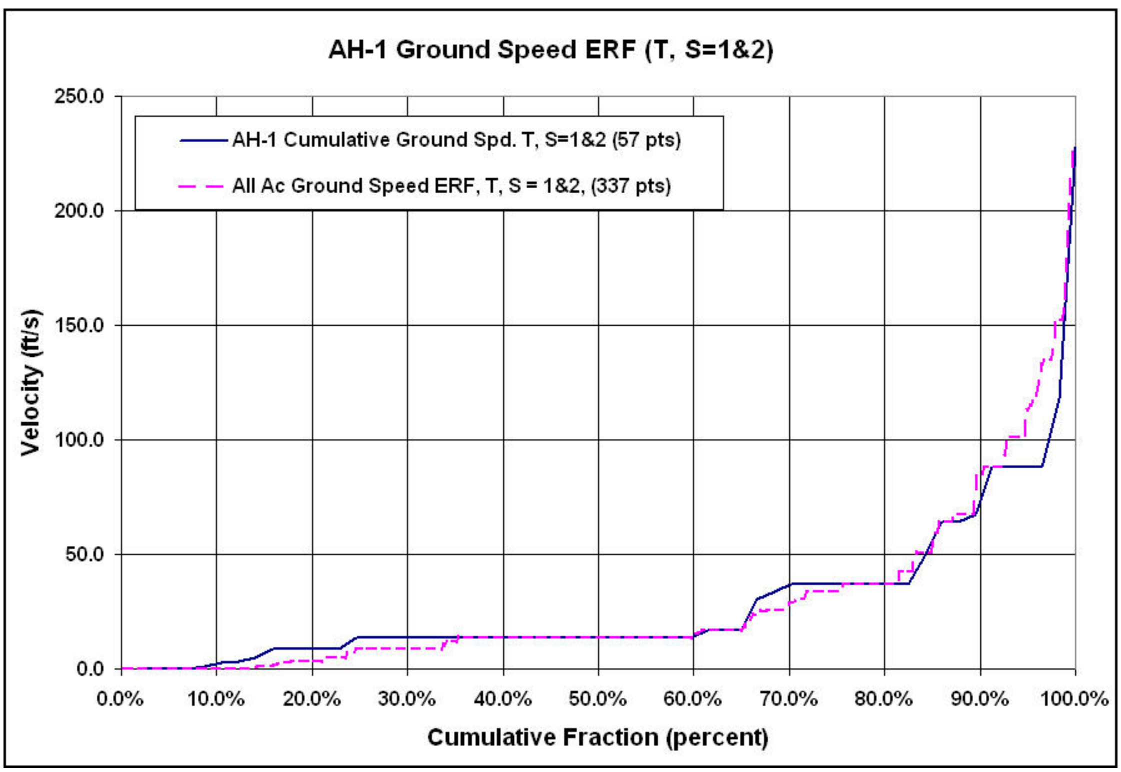

Figure A-2 – AH-1 Ground Speed ERF (T, S=1&2)

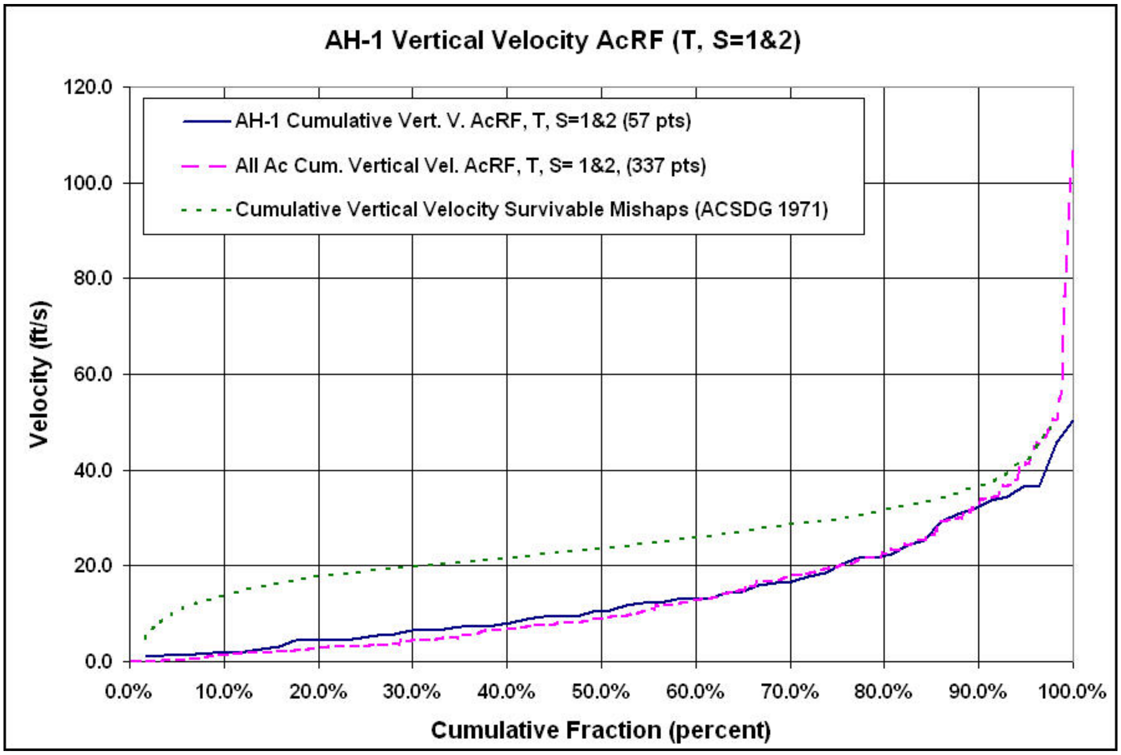

Figure A-3 – AH-1 Vertical Velocity AcRF (T, S=1&2)

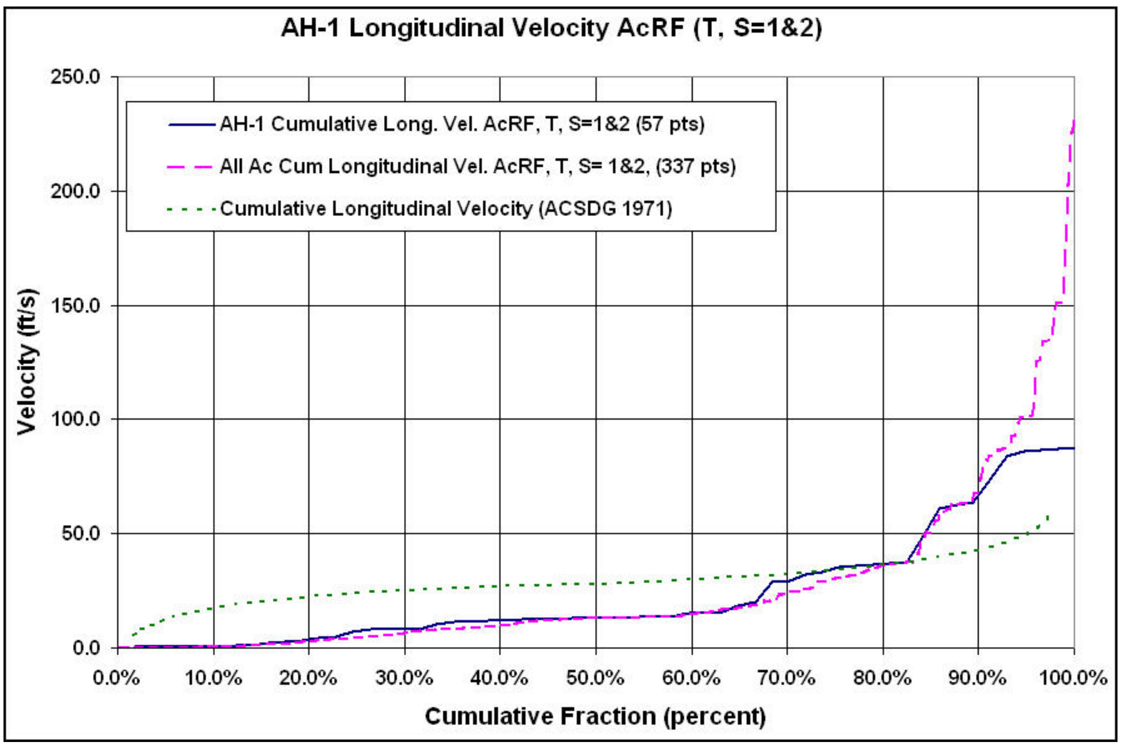

Figure A-4 – AH-1 Longitudinal Velocity AcRF (T, S=1&2)

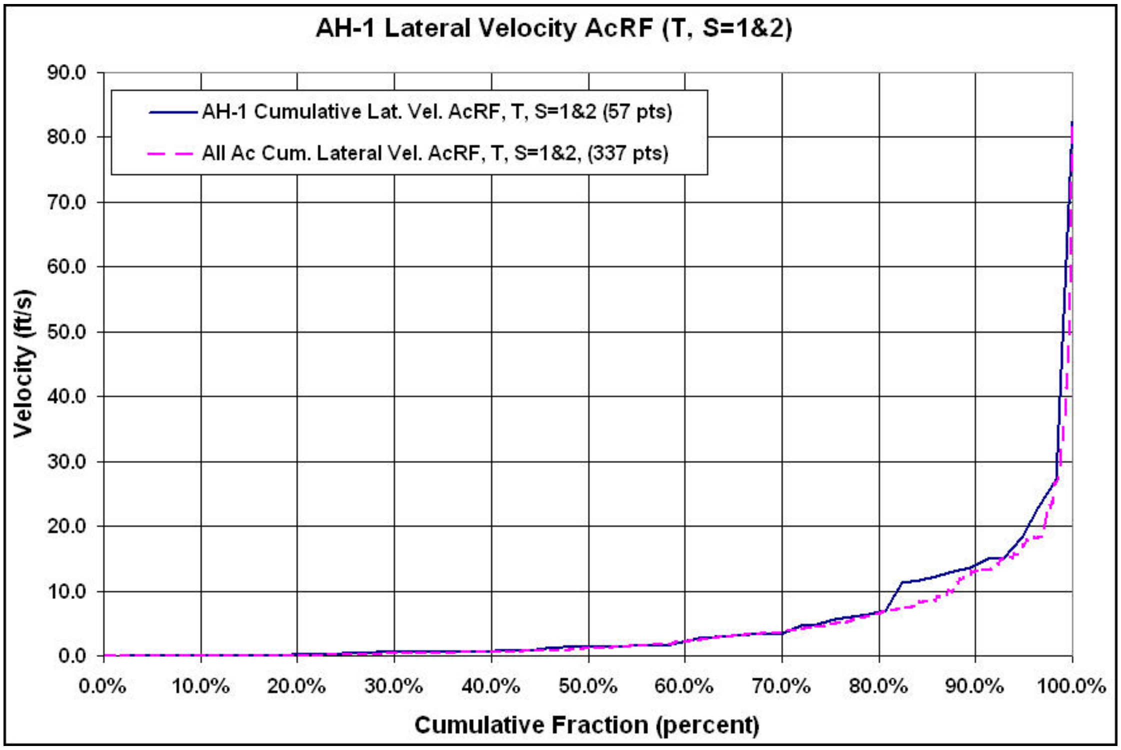

Figure A-5 – AH-1 Lateral Velocity AcRF (T, S=1&2)

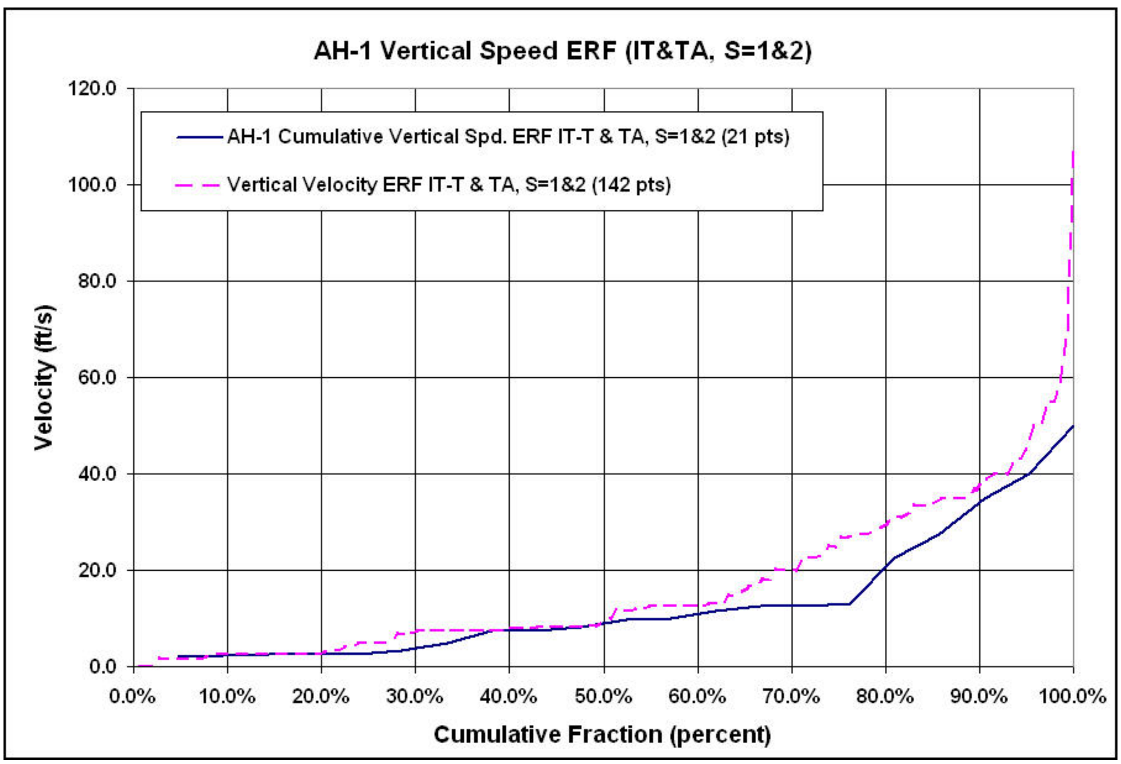

Figure A-6 – AH-1 Vertical Speed ERF (IT&TA, S=1&2)

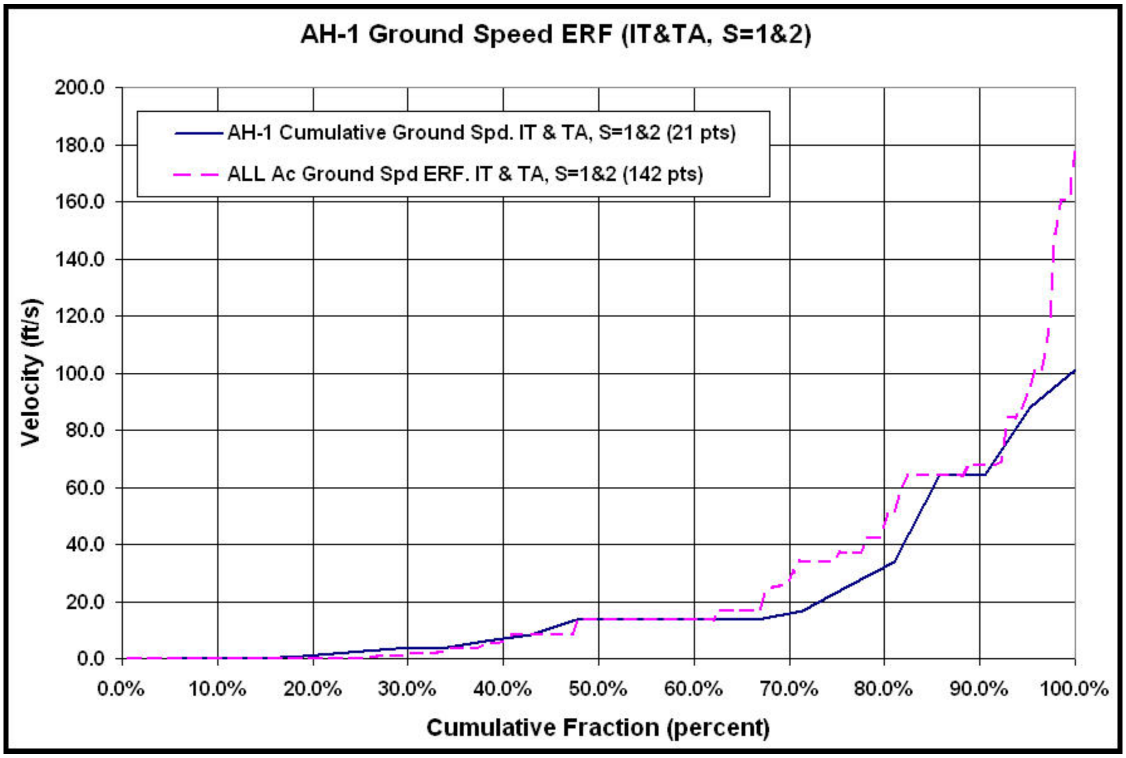

Figure A-7 – AH-1 Ground Speed ERF (IT&TA, S=1&2)

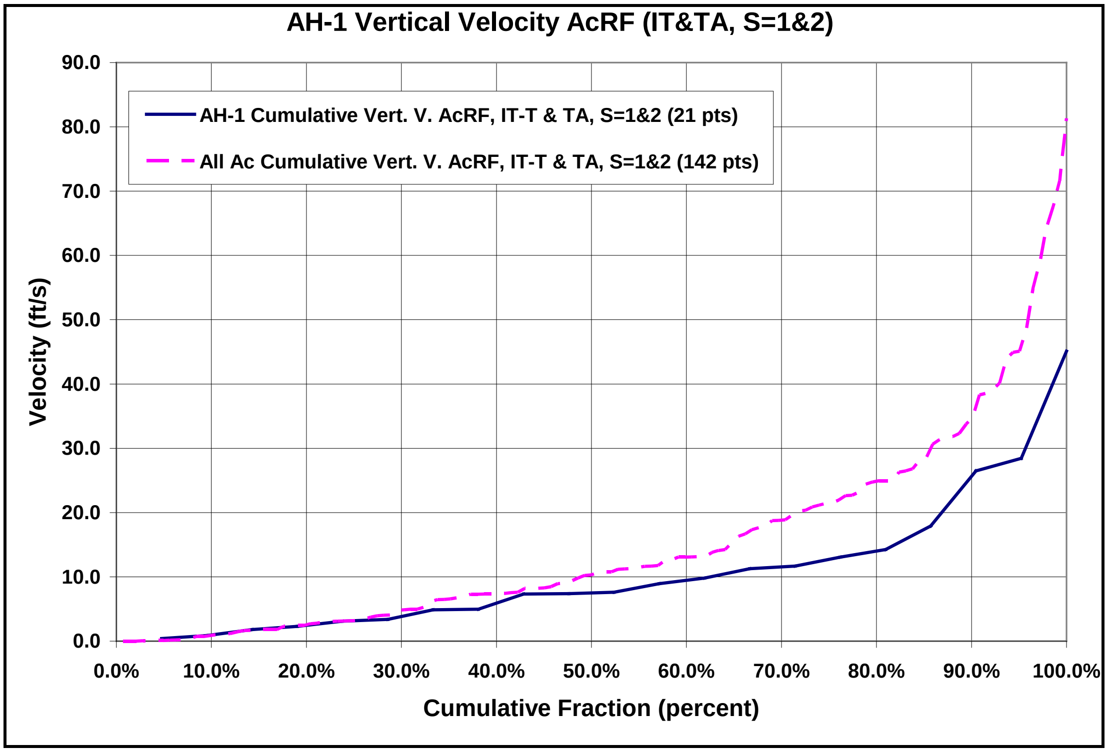

Figure A-8 – AH-1 Vertical Velocity AcRF (IT&TA, S=1&2)

Distribution: Unlimited

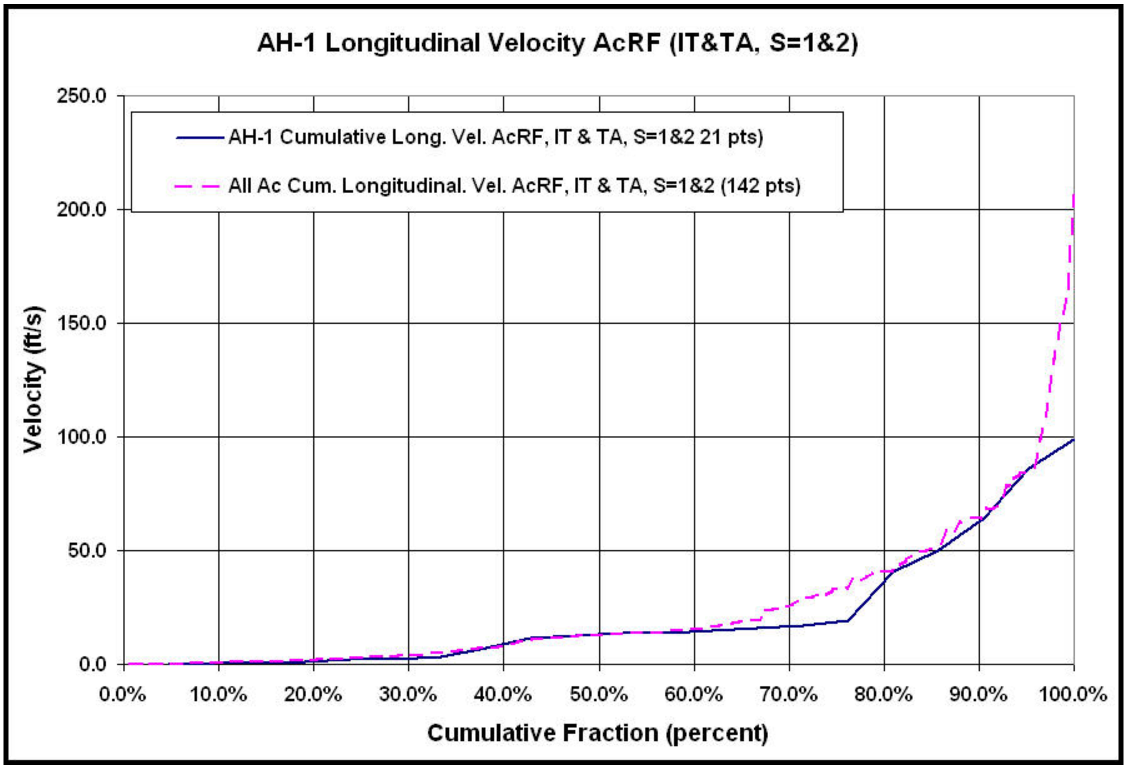

Figure A-9 – AH-1 Longitudinal Velocity AcRF (IT&TA, S=1&2)

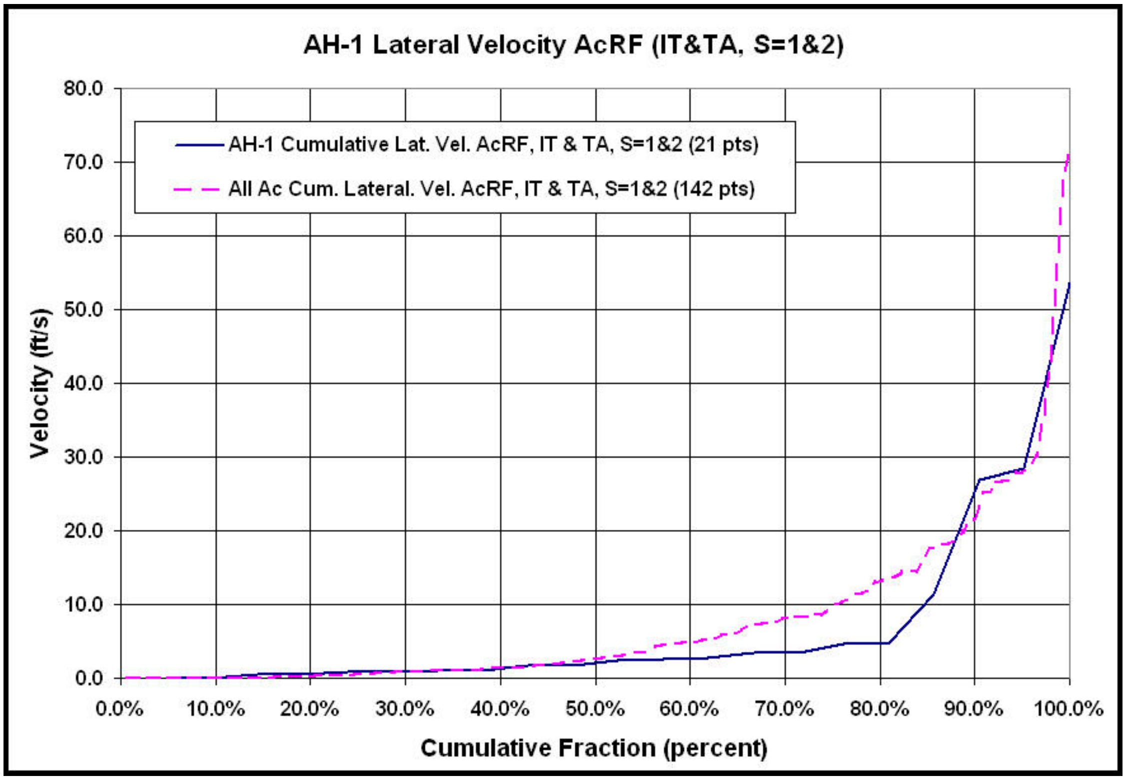

Figure A-10 – AH-1 Lateral Velocity AcRF (IT&TA, S=1&2)

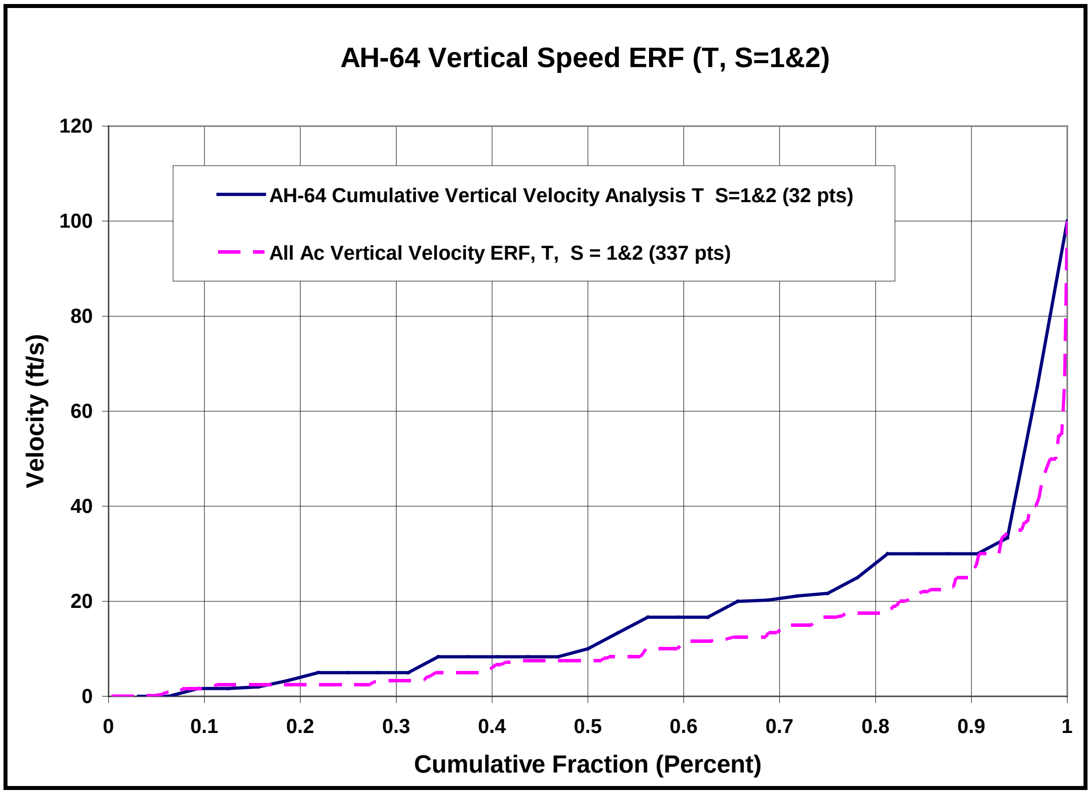

Figure A-11 – AH-64 Vertical Speed ERF (T, S=1&2)

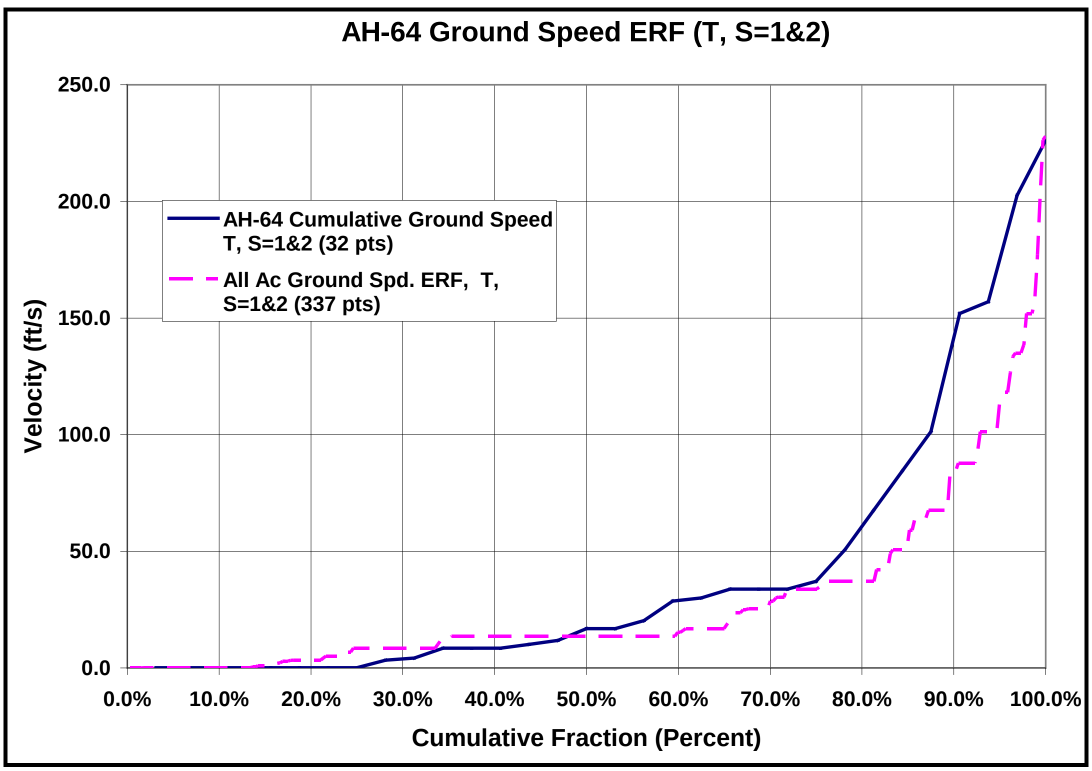

Figure A-12 – AH-64 Ground Speed ERF (T, S=1&2)

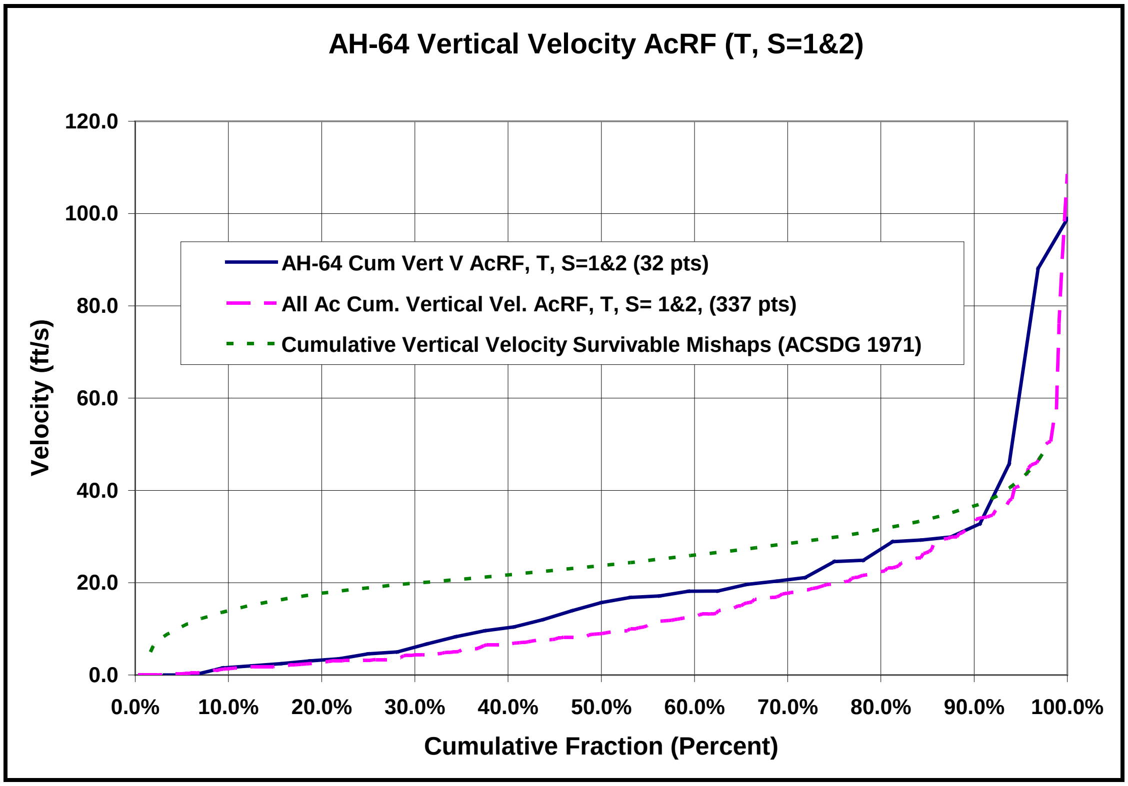

Figure A-13 – AH-64 Vertical Velocity AcRF (T, S=1&2)

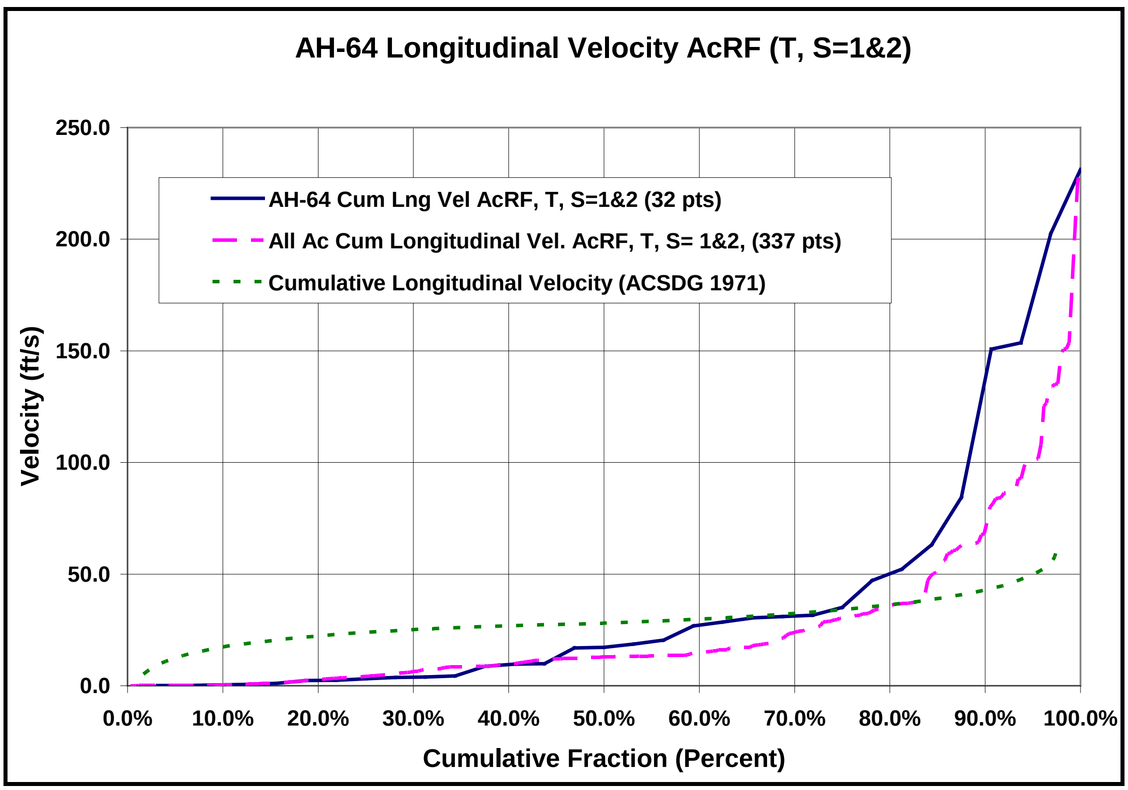

Figure A-14 – AH-64 Longitudinal Velocity AcRF (T, S=1&2)

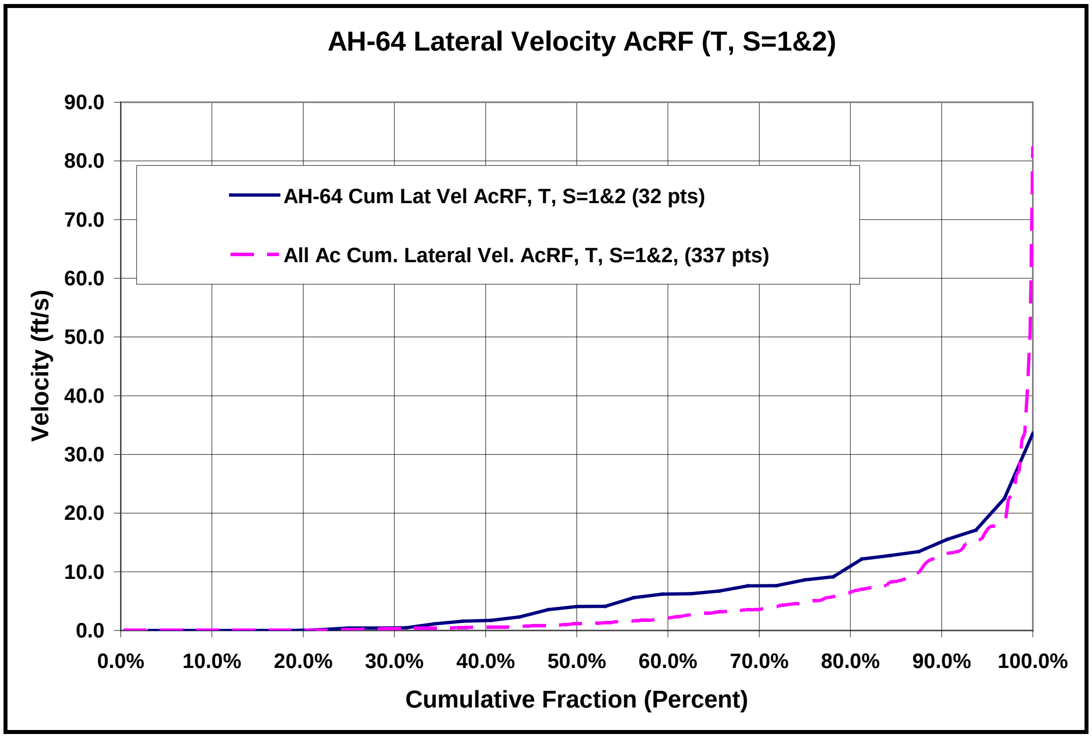

Figure A-15 – AH-64 Lateral Velocity AcRF (T, S=1&2)

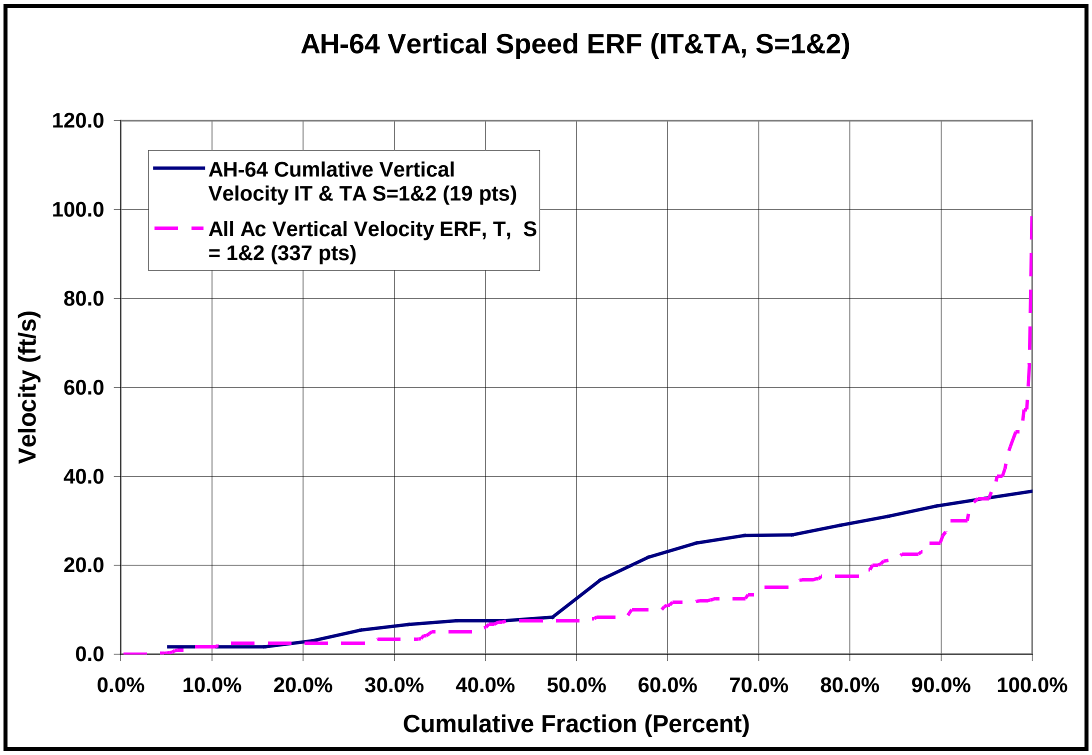

Figure A-16 – AH-64 Vertical Speed ERF (IT&TA, S=1&2)

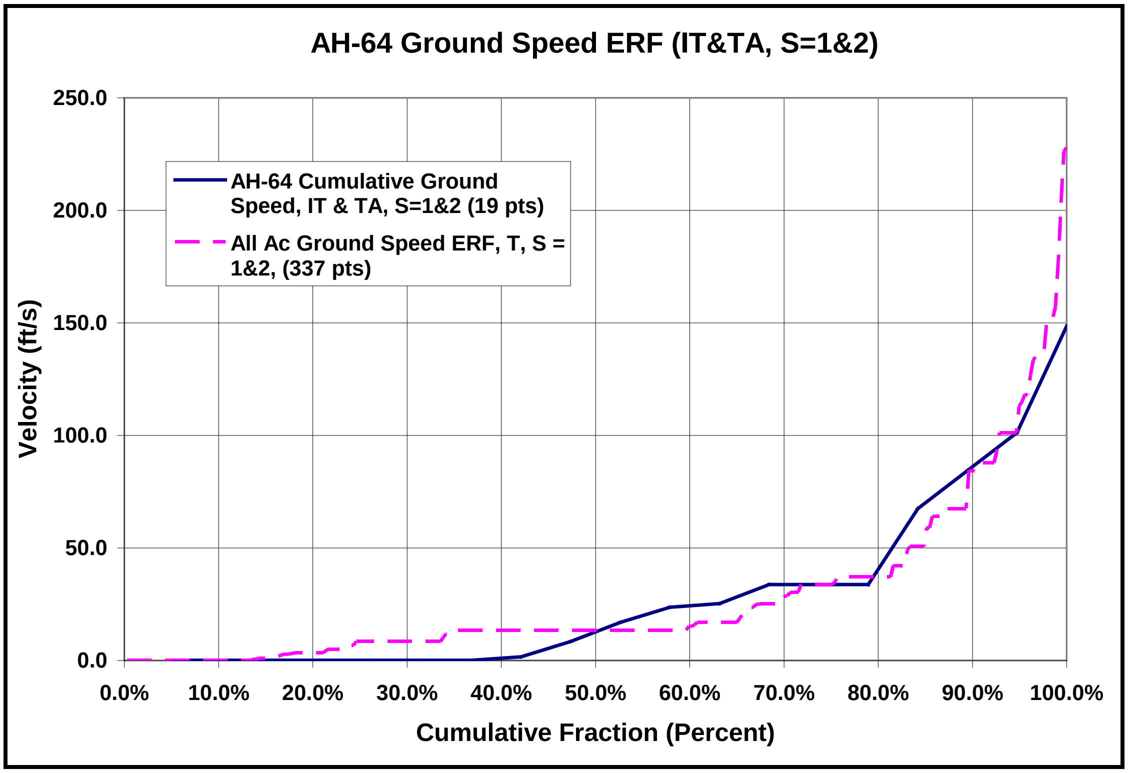

Figure A-17 – AH-64 Ground Speed ERF (IT&TA, S=1&2)

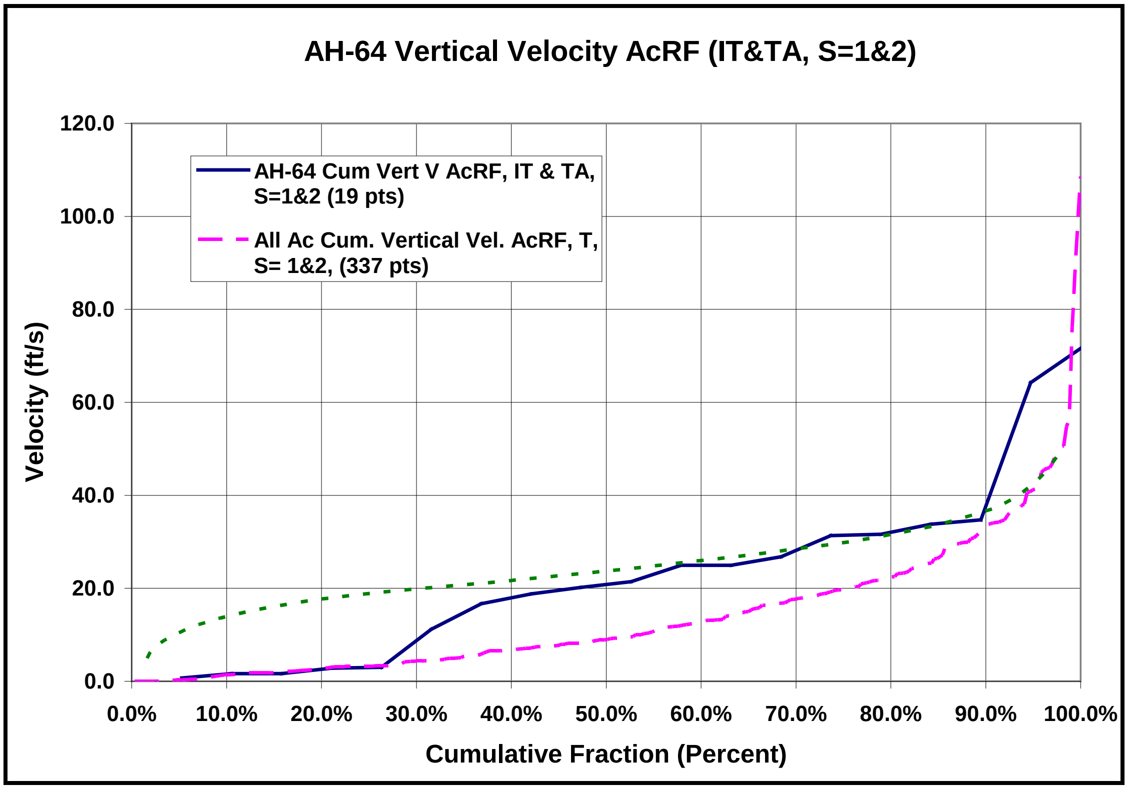

Figure A-18 – AH-64 Vertical Velocity AcRF (IT&TA, S=1&2)

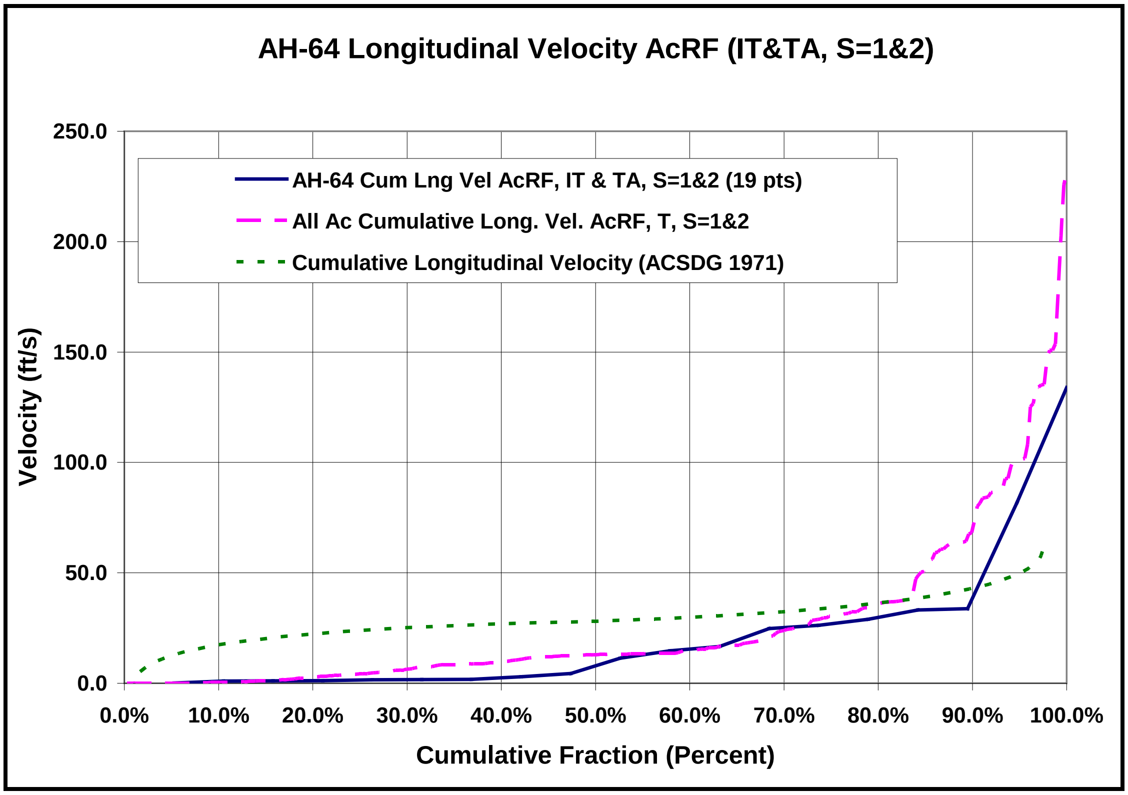

Figure A-19 – AH-64 Longitudinal Velocity AcRF (IT&TA, S=1&2)

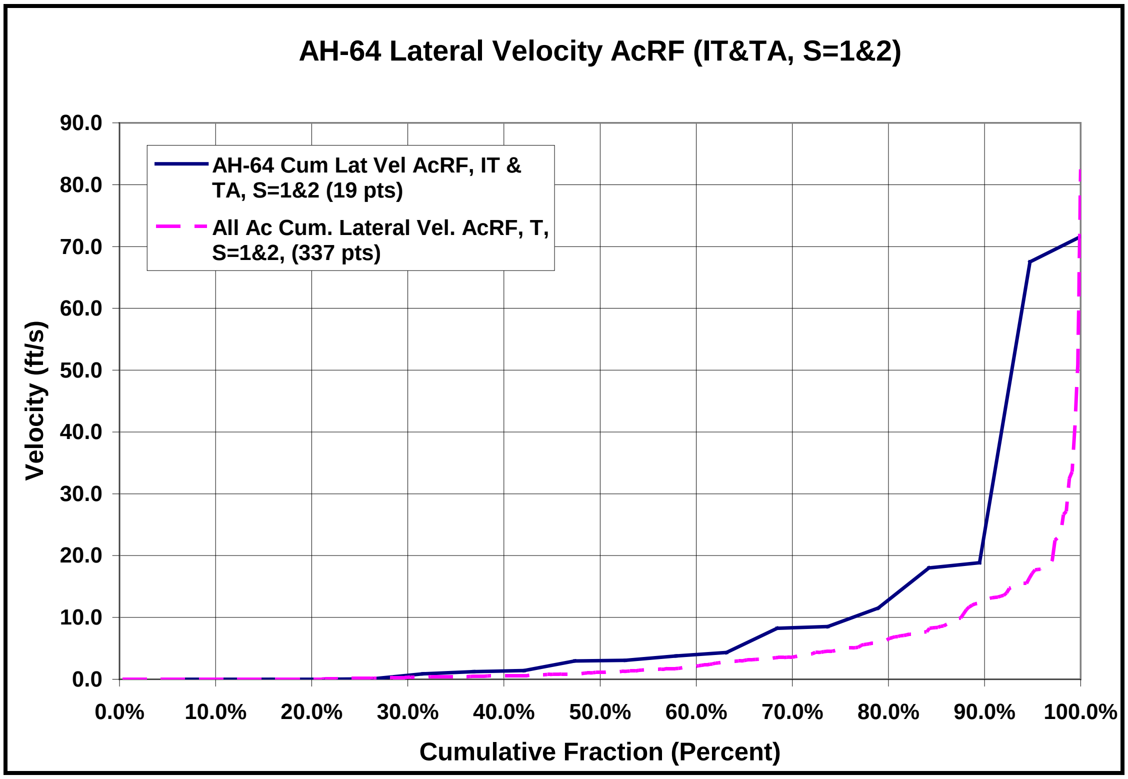

Figure A-20 – AH-64 Lateral Velocity AcRF (IT&TA, S=1&2)

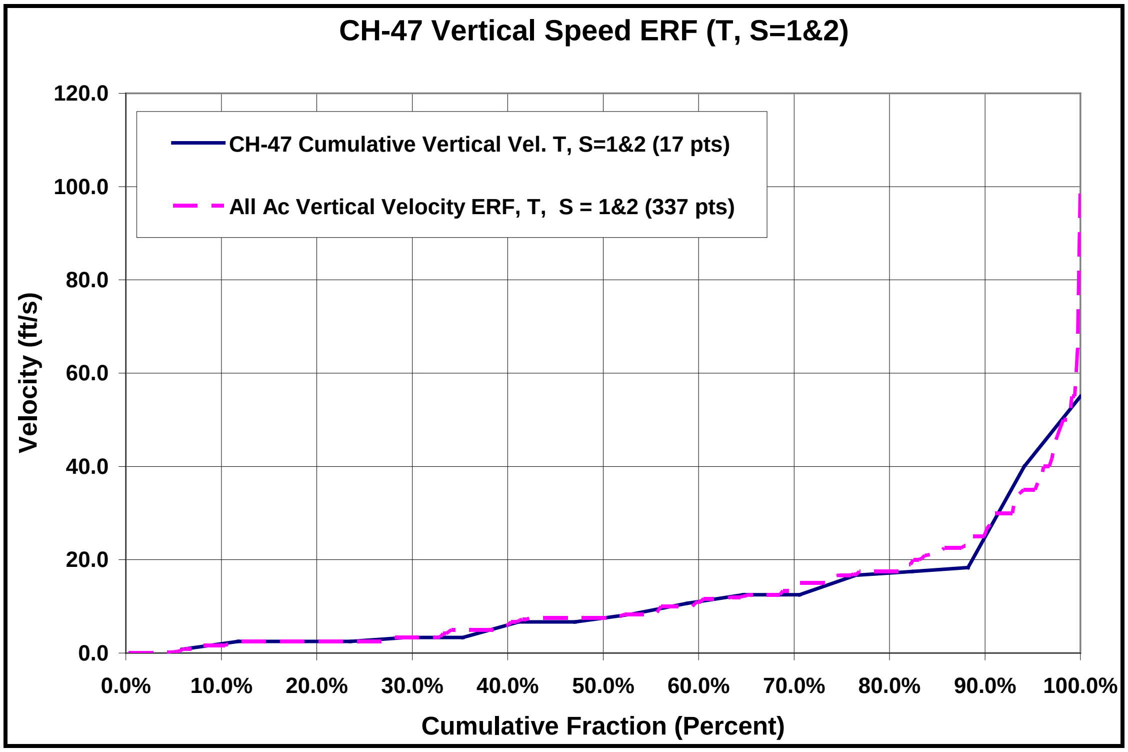

Figure A-21 – CH-47 Vertical Speed ERF (T, S=1&2)

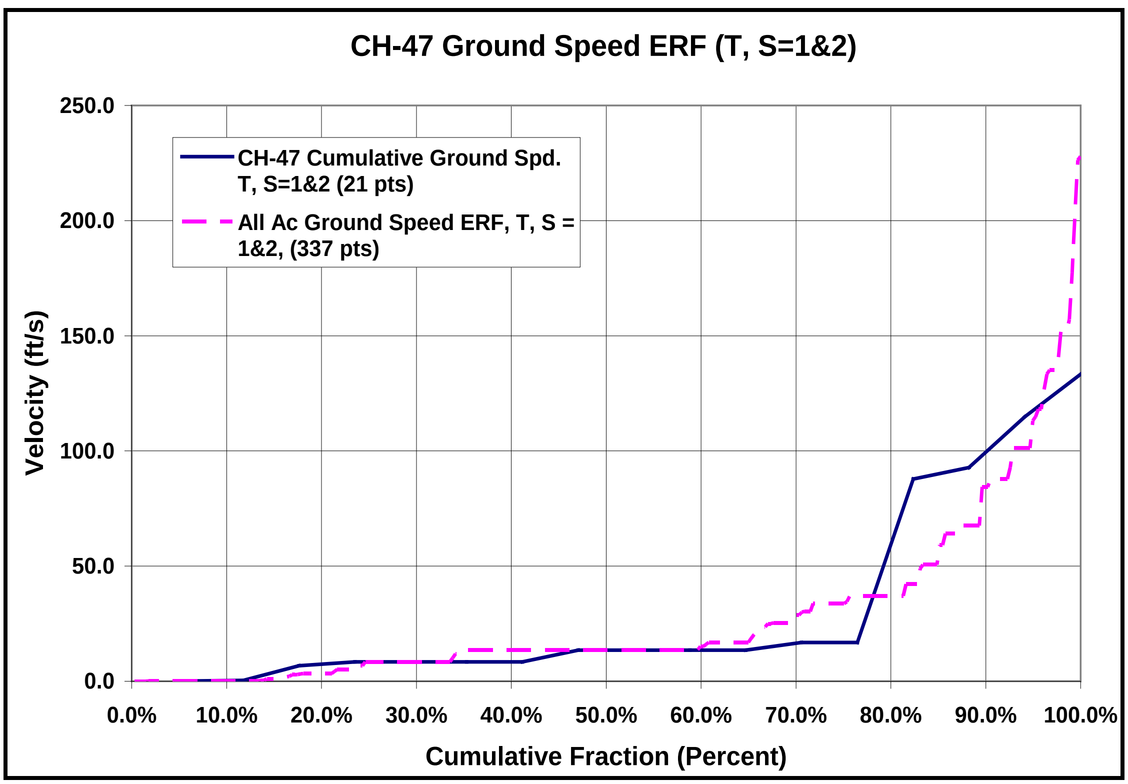

Figure A-22 – CH-47 Ground Speed ERF (T, S=1&2)

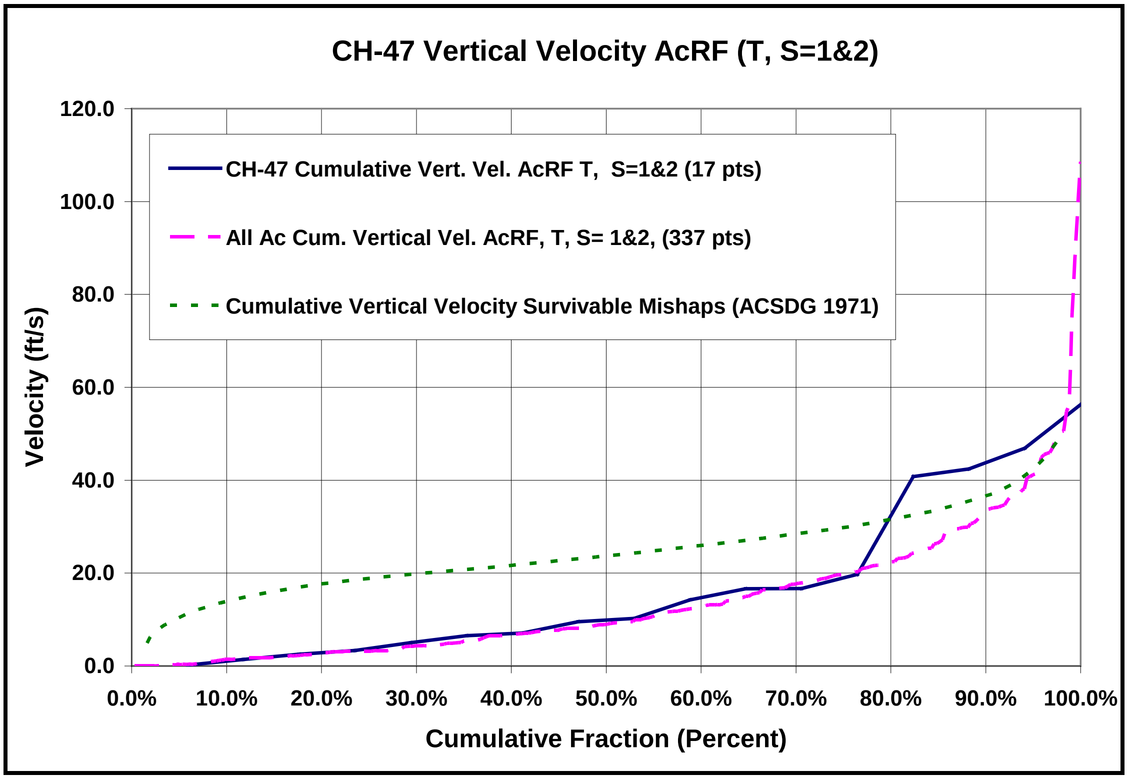

Figure A-23 – CH-47 Vertical Velocity AcRF (T, S=1&2)

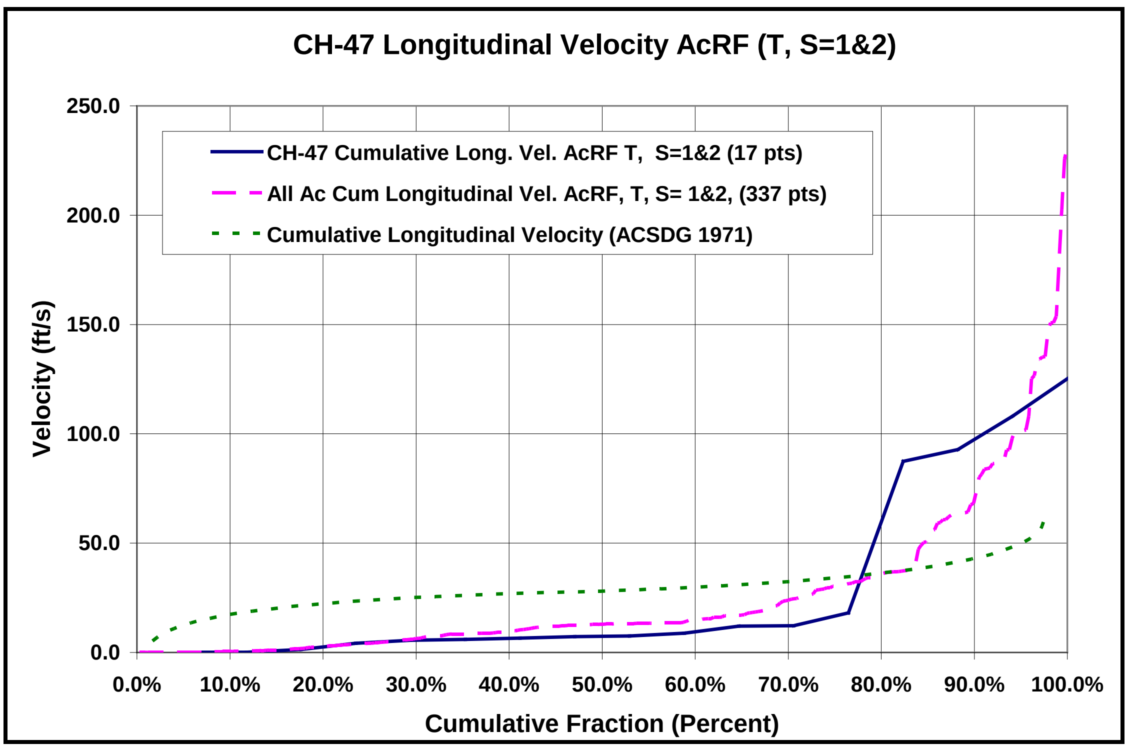

Figure A-24 – CH-47 Longitudinal Velocity AcRF (T, S=1&2)

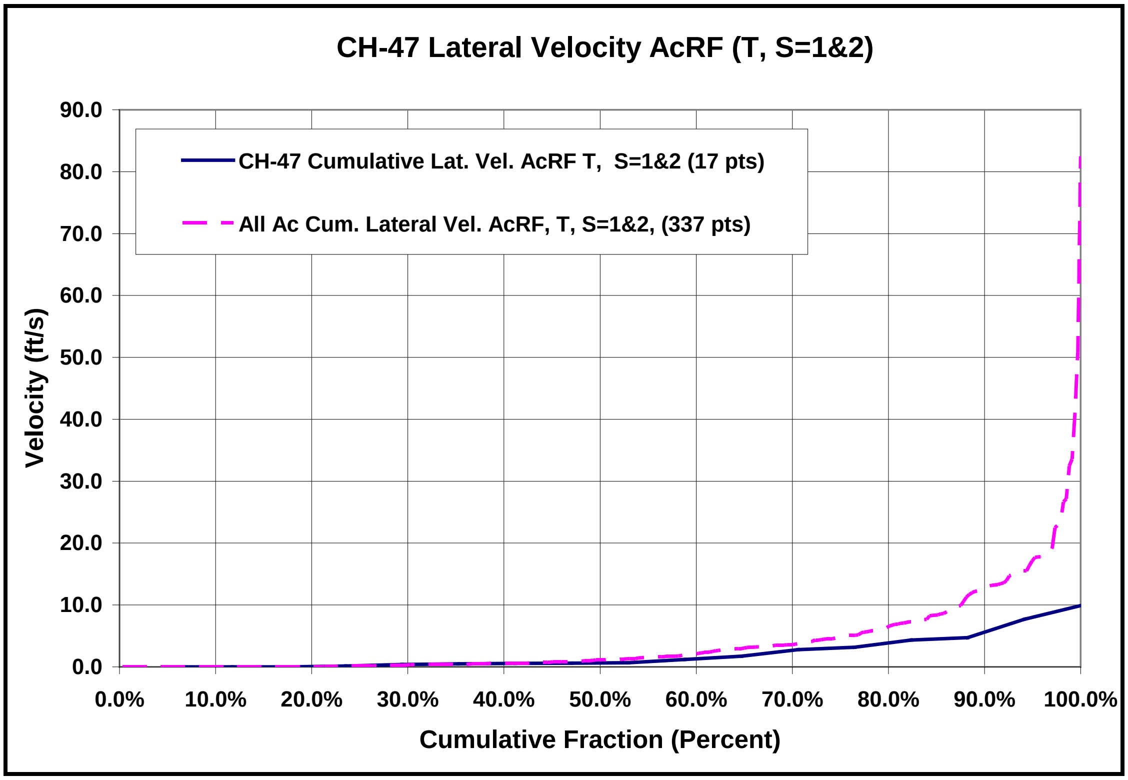

Figure A-25 – CH-47 Lateral Velocity AcRF (T, S=1&2)

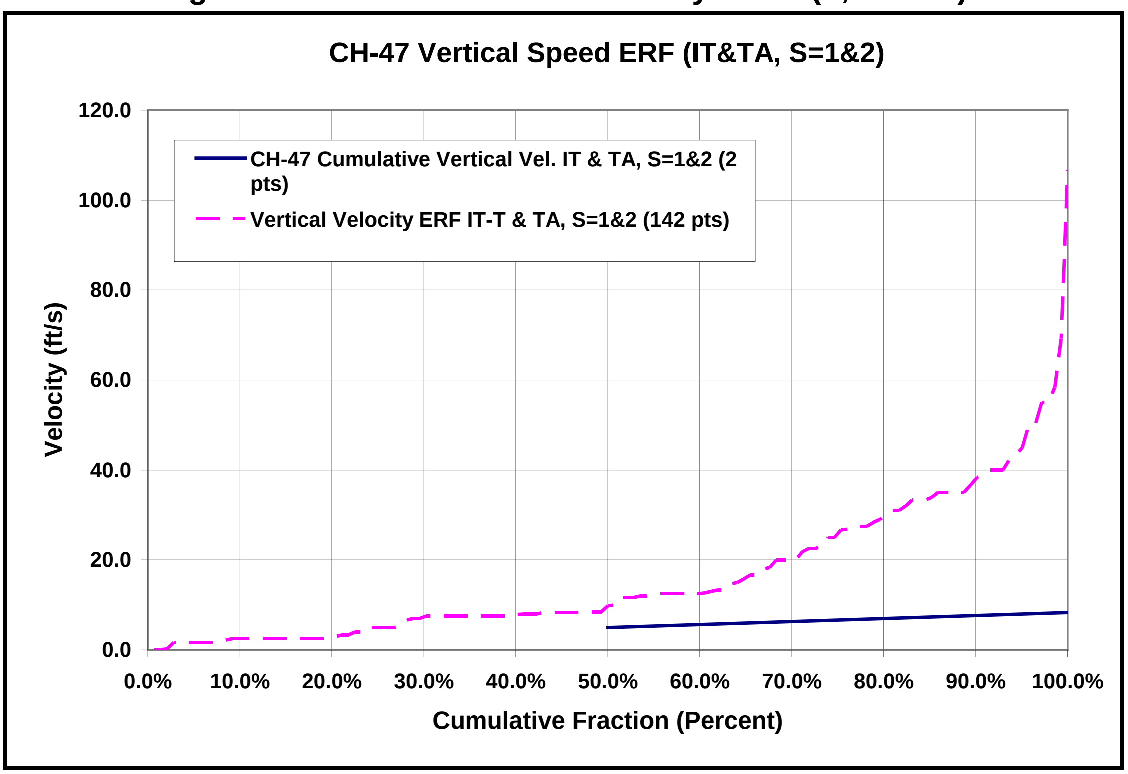

Figure A-26 – CH-47 Vertical Speed ERF (IT&TA, S=1&2)

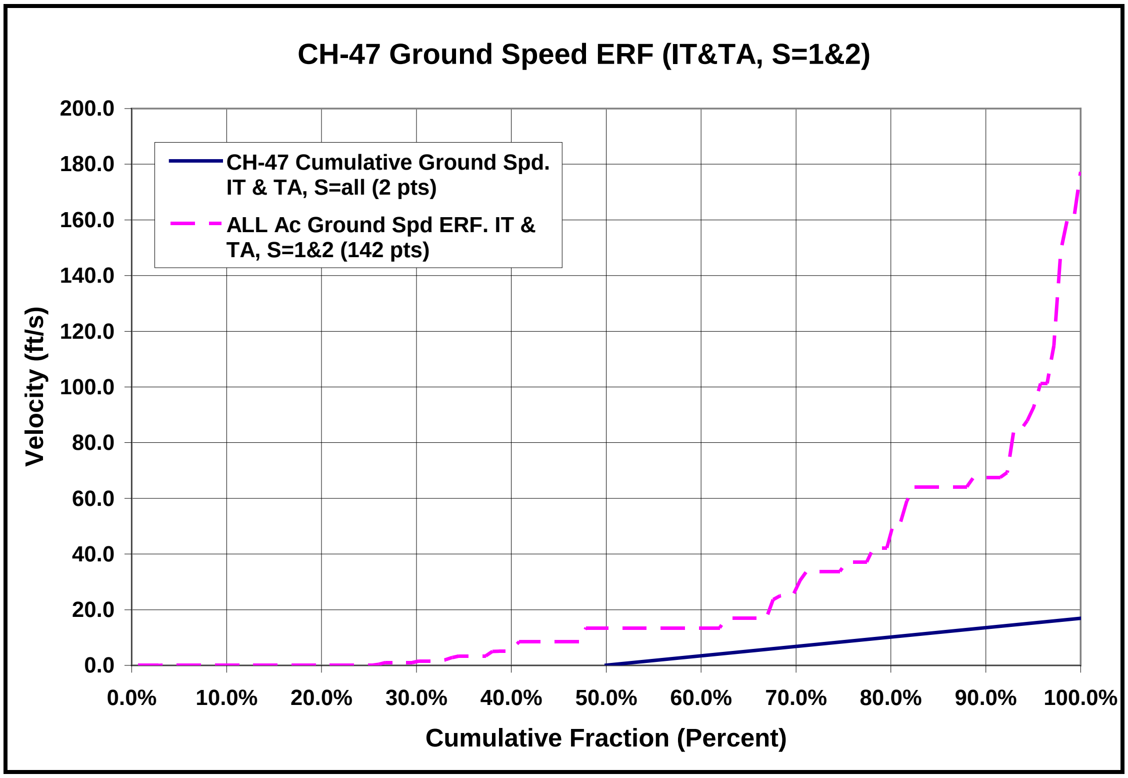

Figure A-27 – CH-47 Ground Speed ERF (IT&TA, S=1&2)

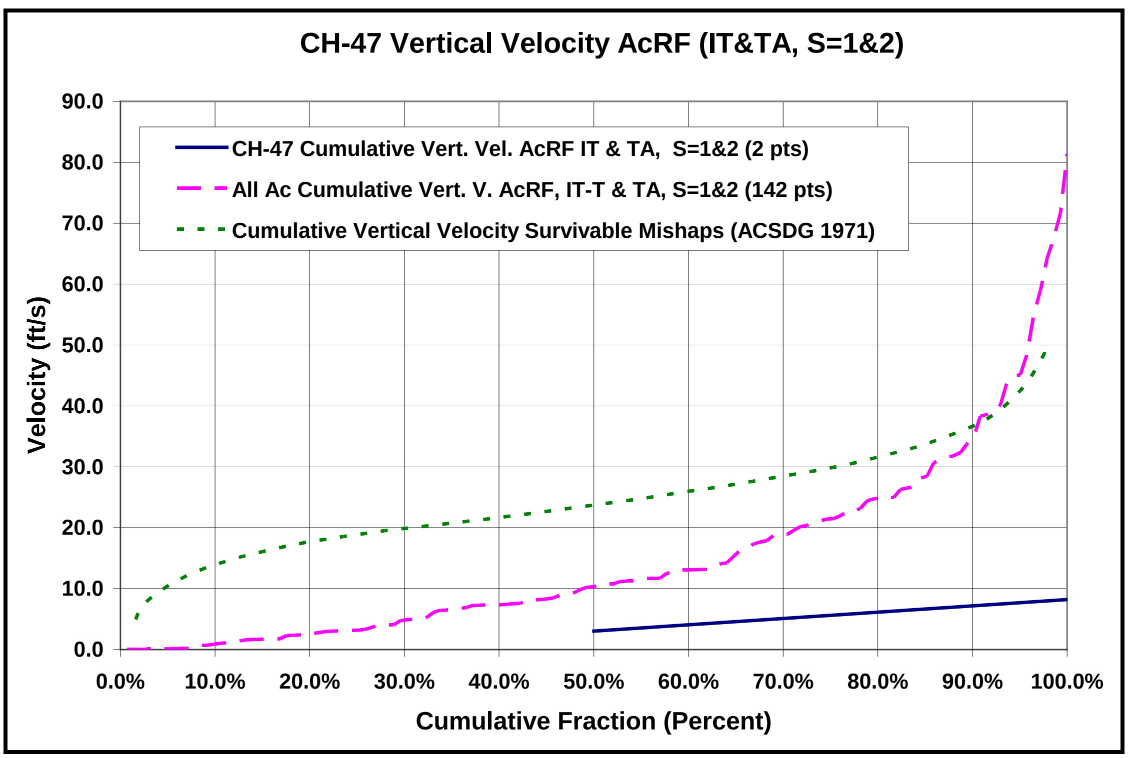

Figure A-28 – CH-47 Vertical Velocity AcRF (IT&TA, S=1&2)

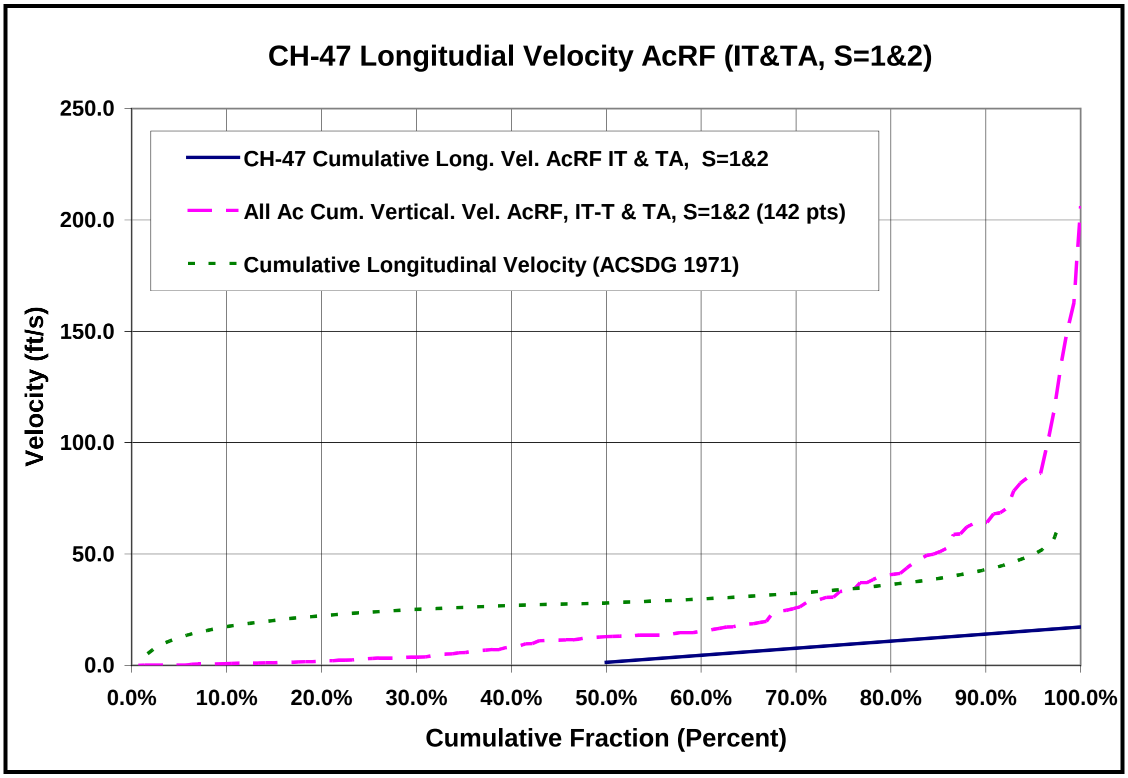

Figure A-29 – CH-47 Longitudinal Velocity AcRF (IT&TA, S=1&2)

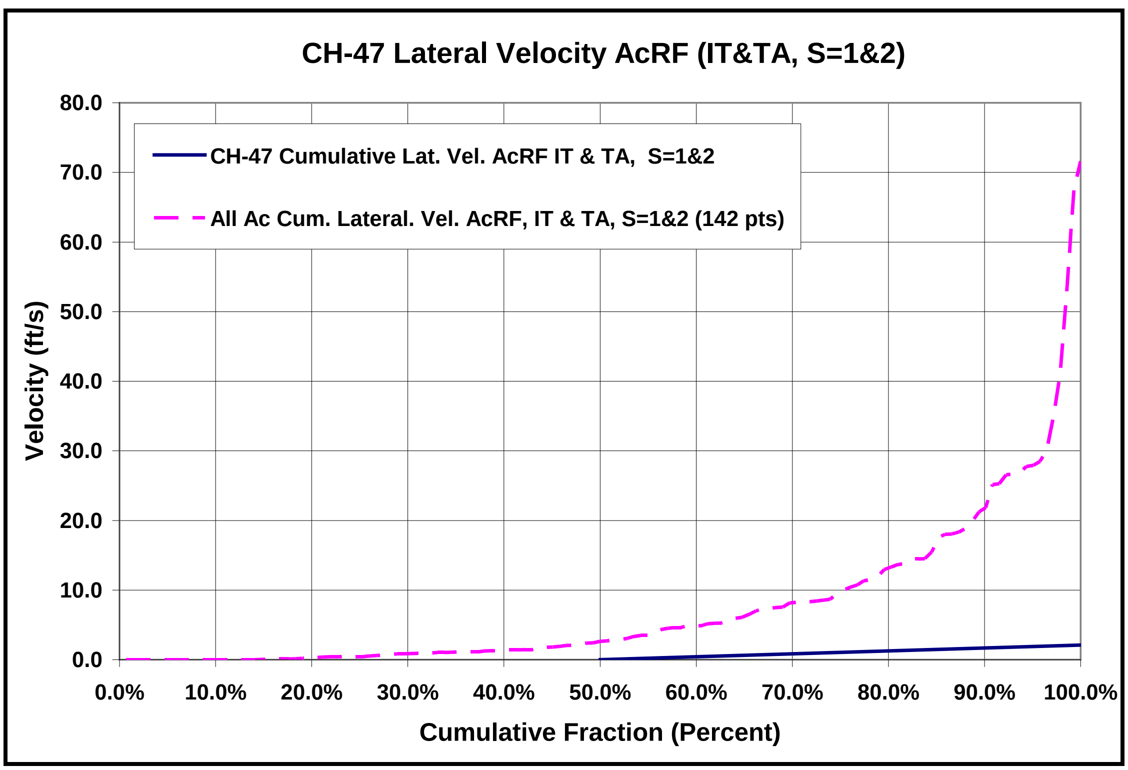

Figure A-30 – CH-47 Lateral Velocity AcRF (IT&TA, S=1&2)

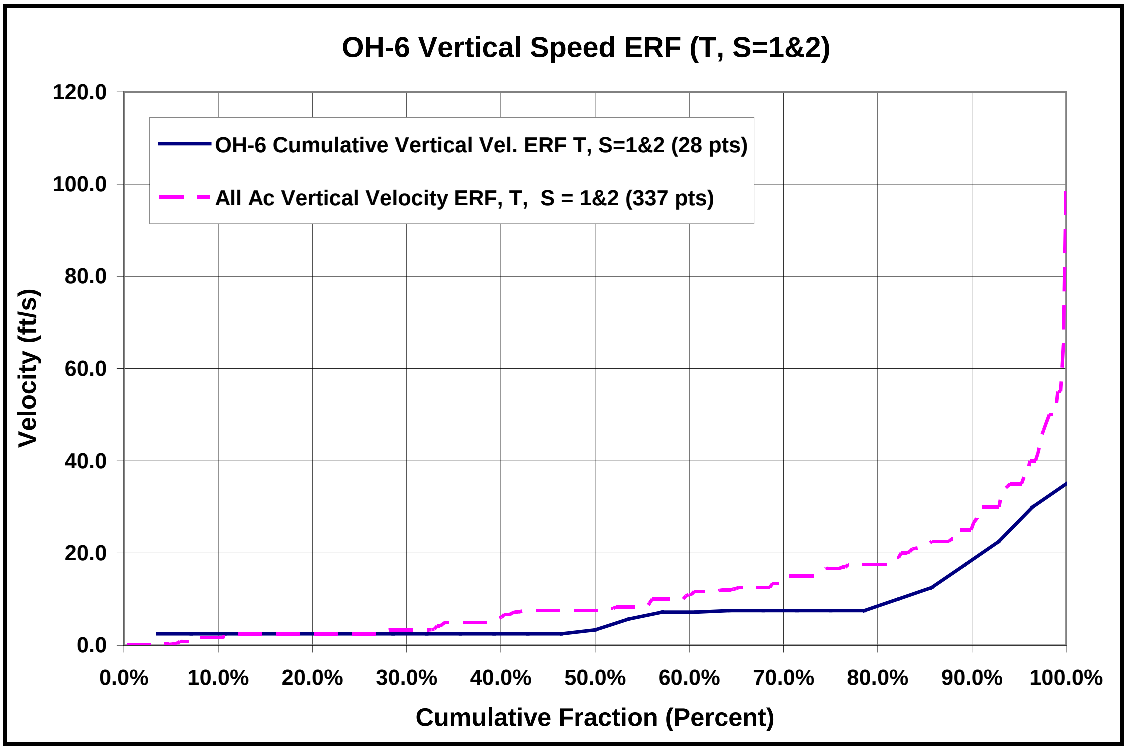

Figure A-31 – OH-6 Vertical Speed ERF (T, S=1&2)

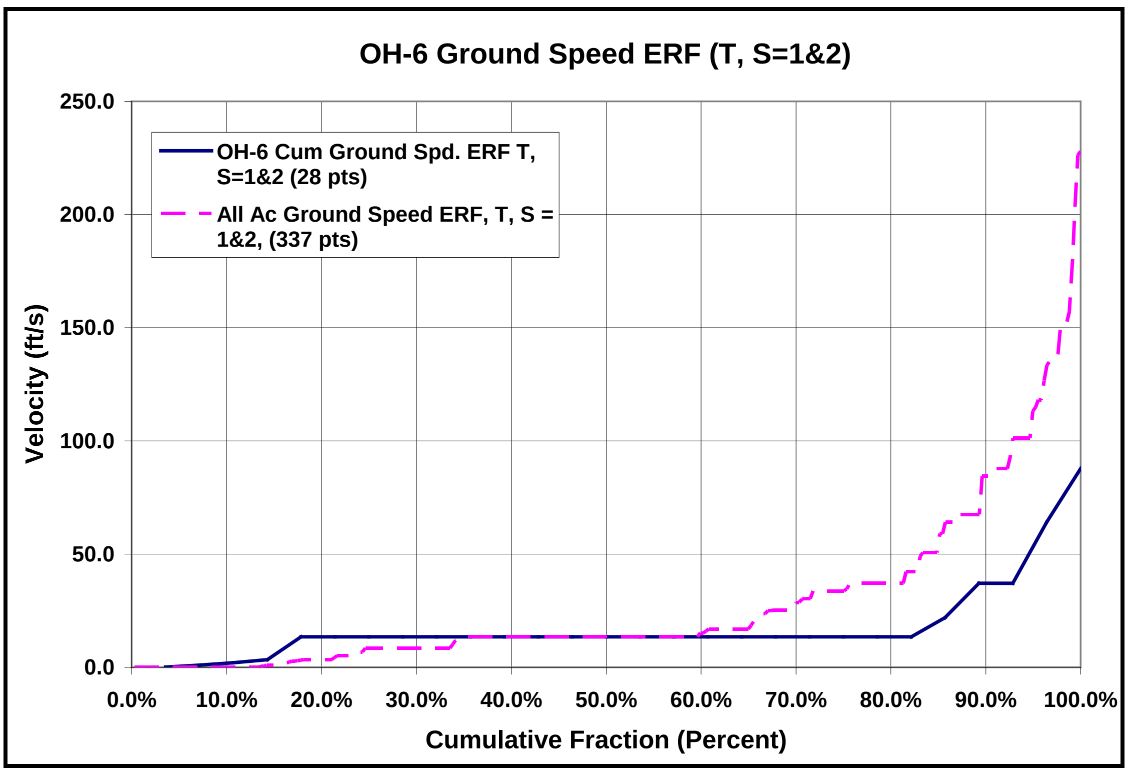

Figure A-32 – OH-6 Ground Speed ERF (T, S=1&2)

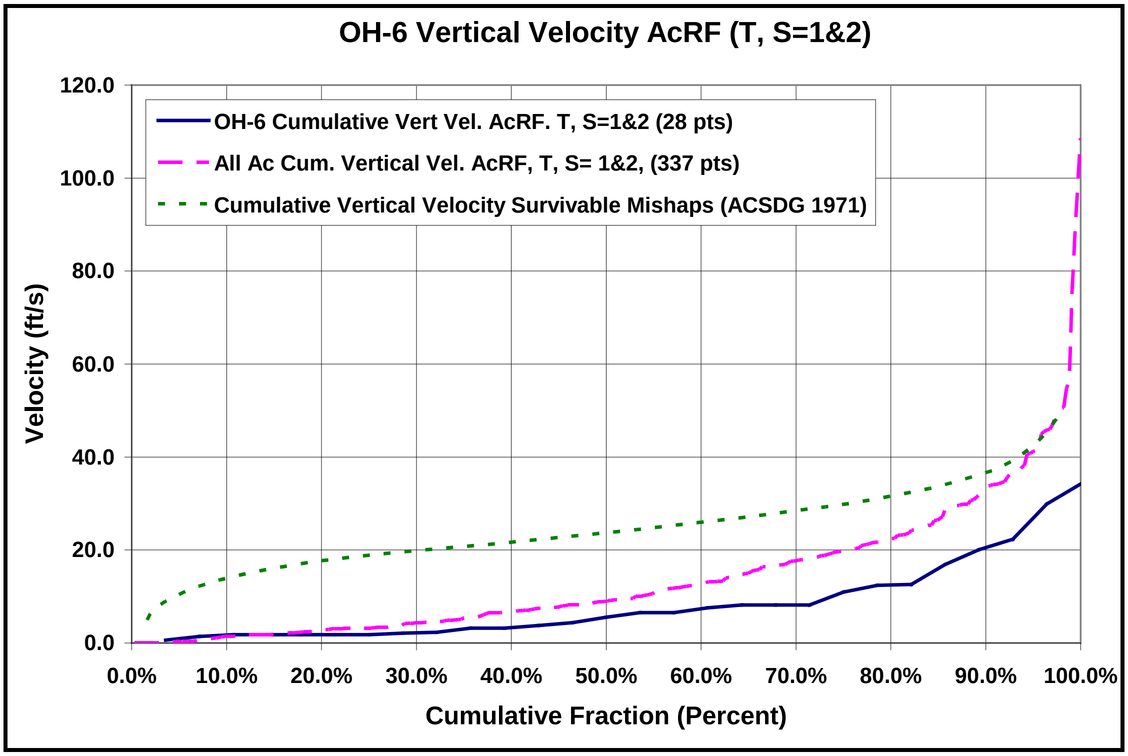

Figure A-33 – OH-6 Vertical Velocity AcRF (T, S=1&2)

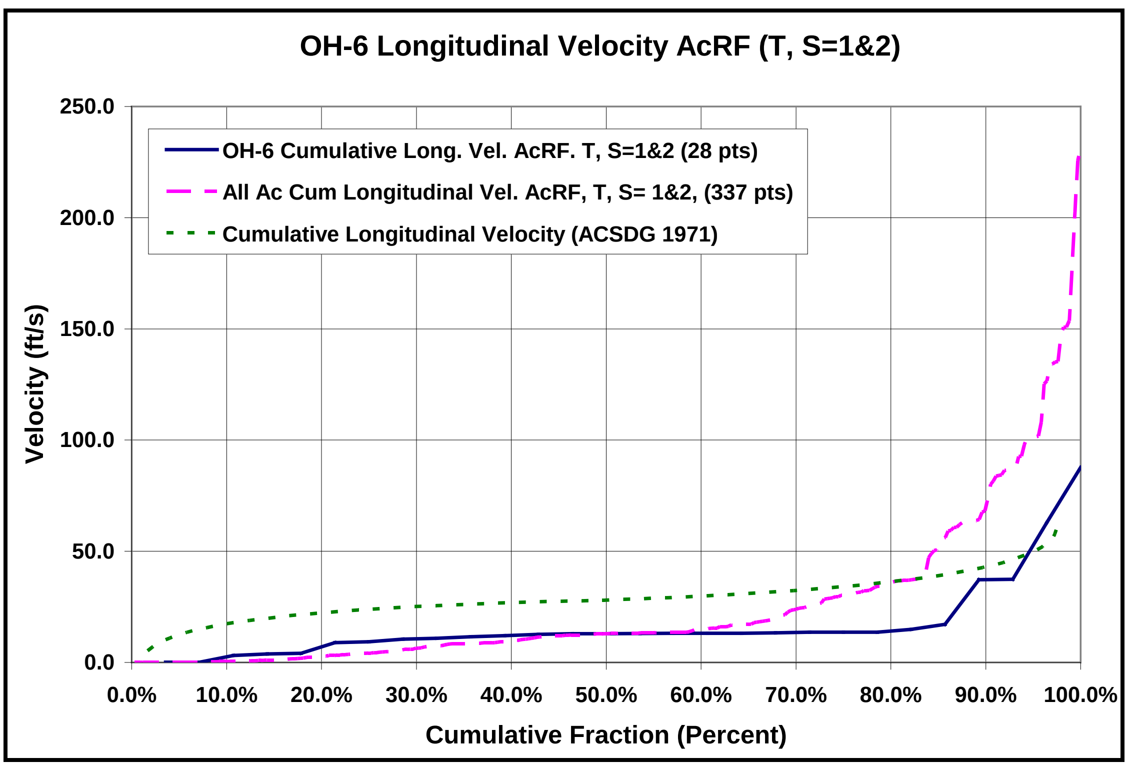

Figure A-34 – OH-6 Longitudinal Velocity AcRF (T, S=1&2)

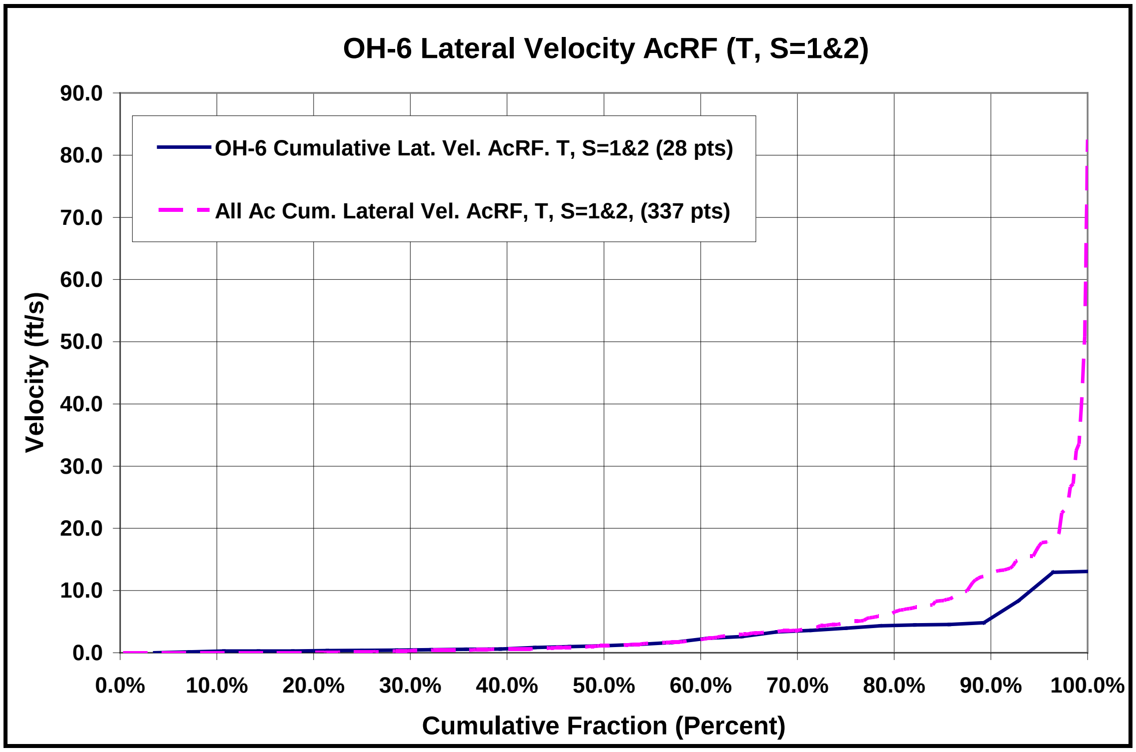

Figure A-35 – OH-6 Lateral Velocity AcRF (T, S=1&2)

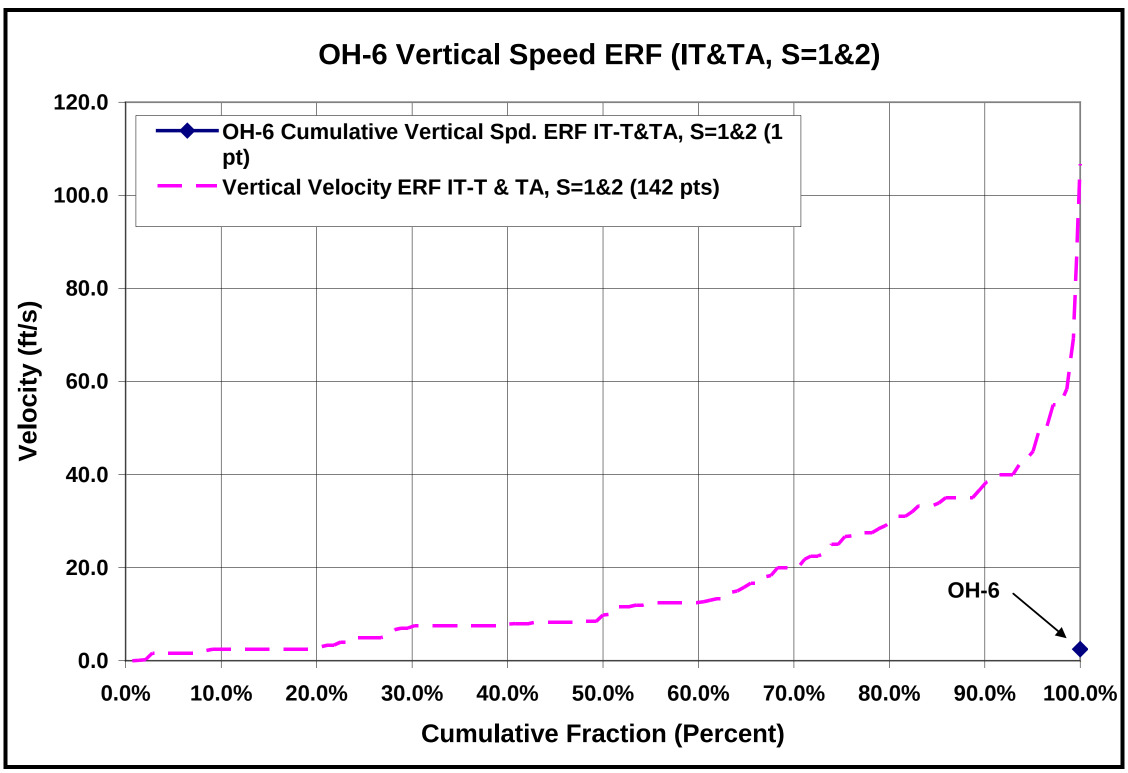

Figure A-36 – OH-6 Vertical Speed ERF (IT&TA, S=1&2)

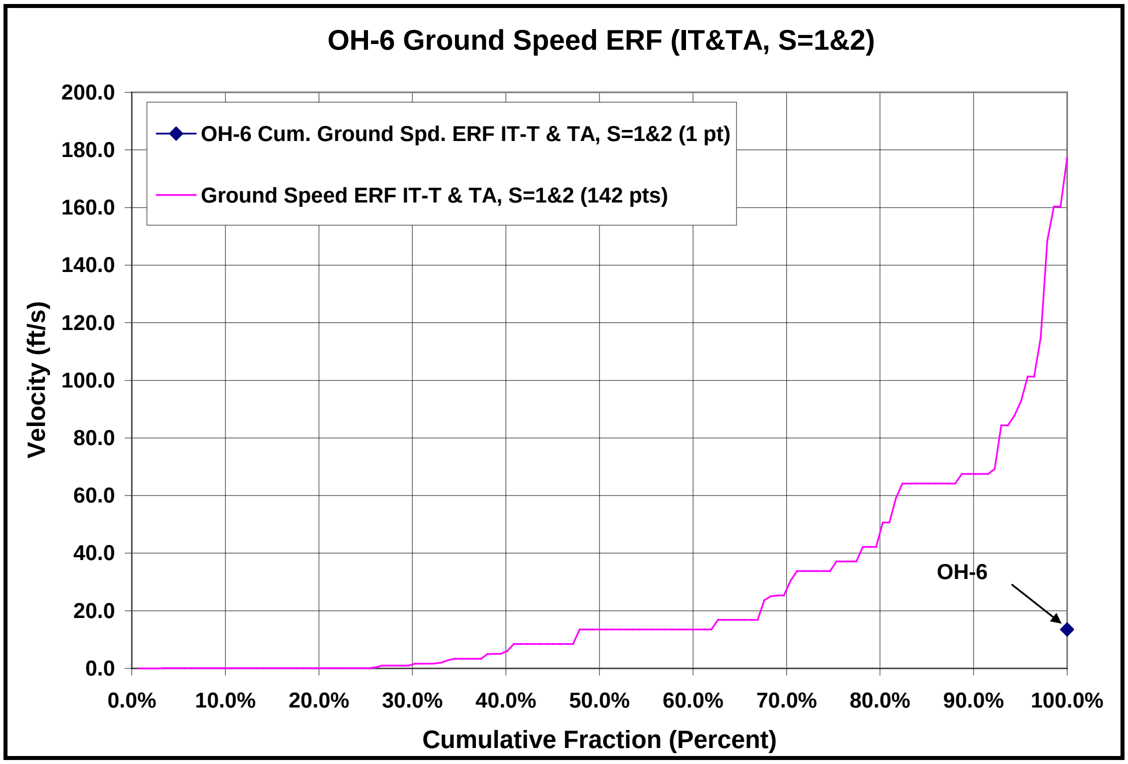

Figure A-37 – OH-6 Ground Speed ERF (IT&TA, S=1&2)

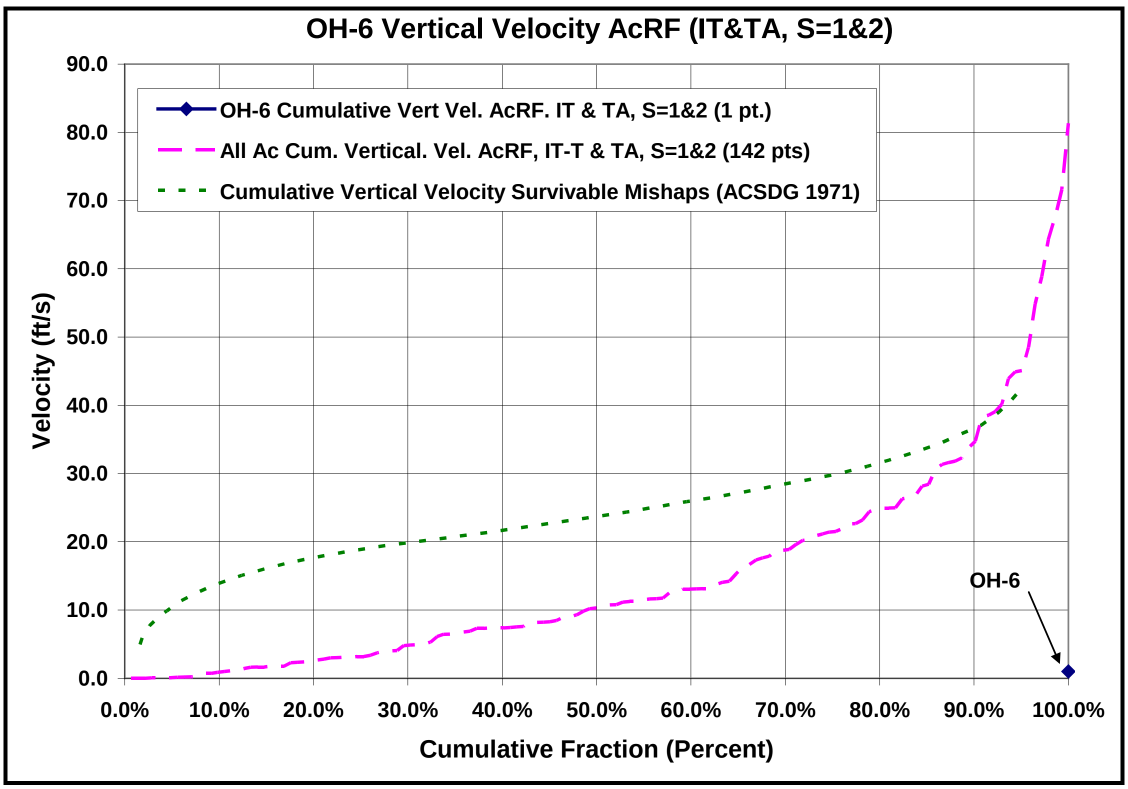

Figure A-38 – OH-6 Vertical Velocity AcRF (IT&TA, S=1&2)

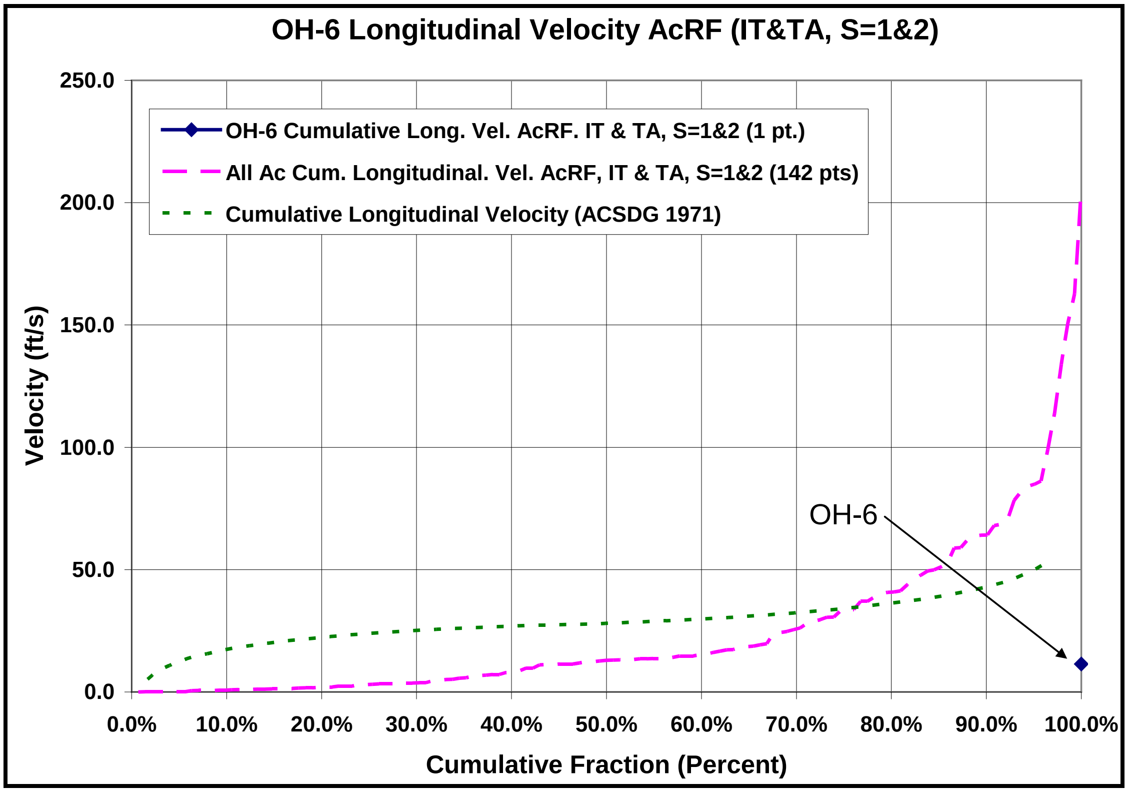

Figure A-39 – OH-6 Longitudinal Velocity AcRF (IT&TA, S=1&2)

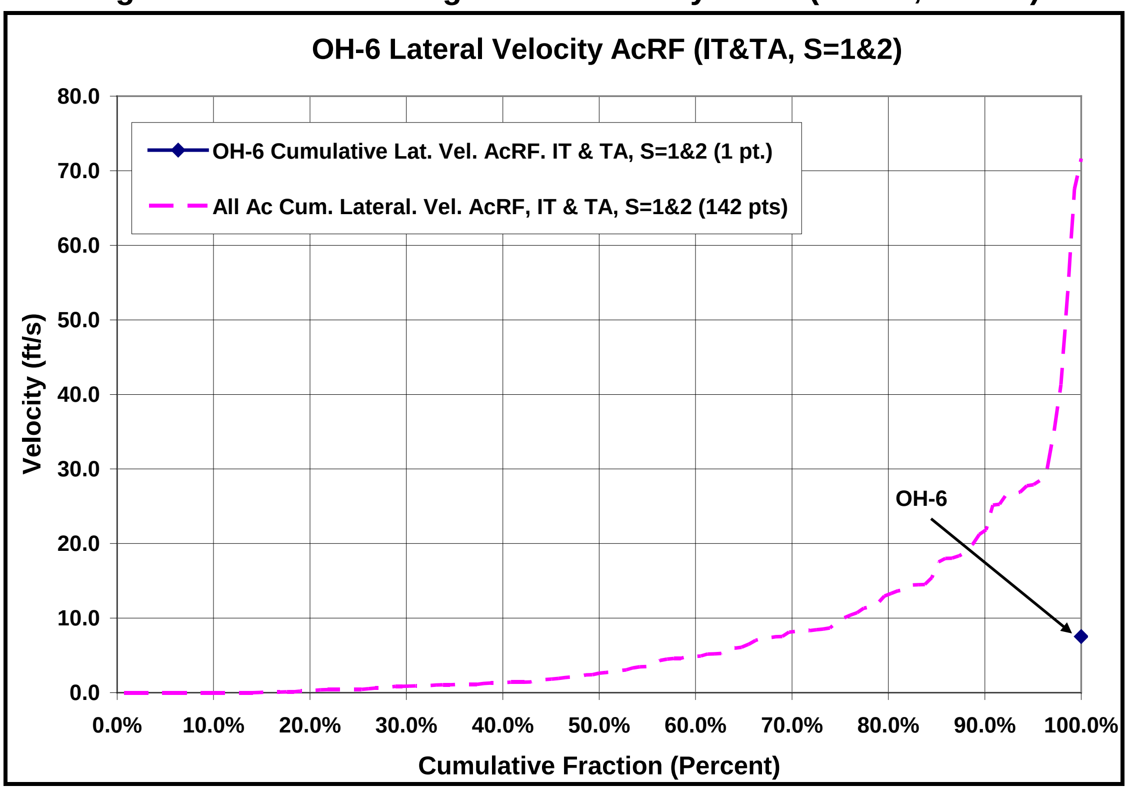

Figure A-40 – OH-6 Lateral Velocity AcRF (IT&TA, S=1&2)

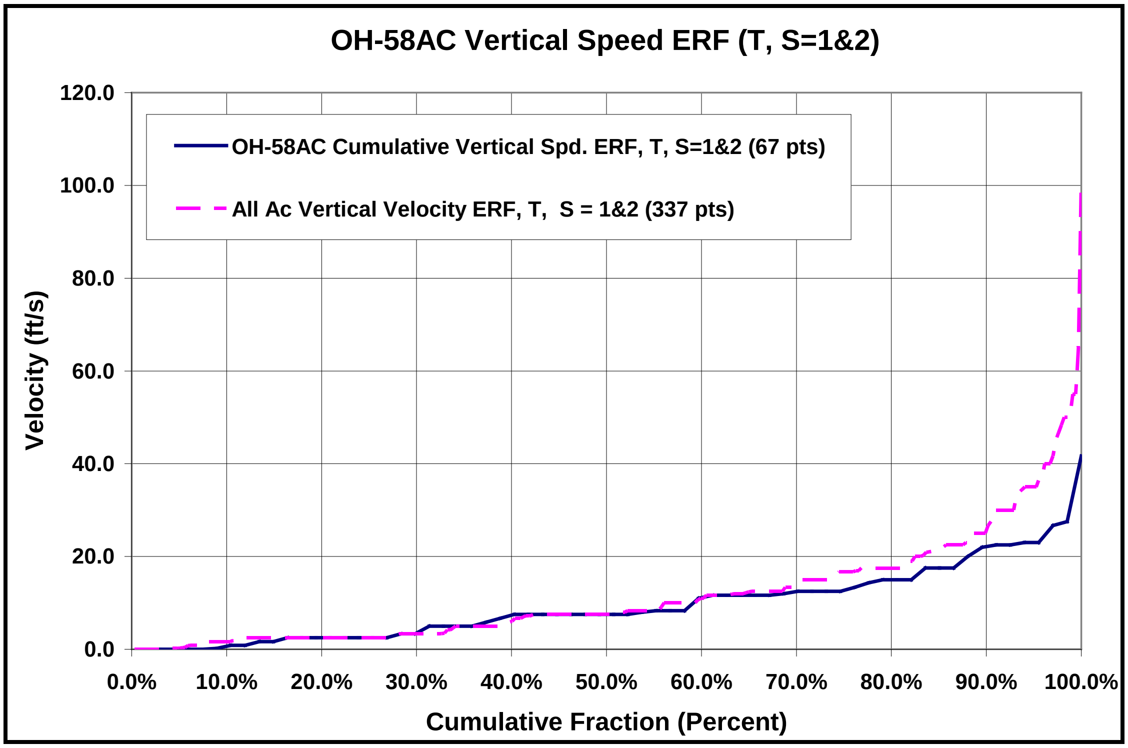

Figure A-41 – OH-58AC Vertical Speed ERF (T, S=1&2)

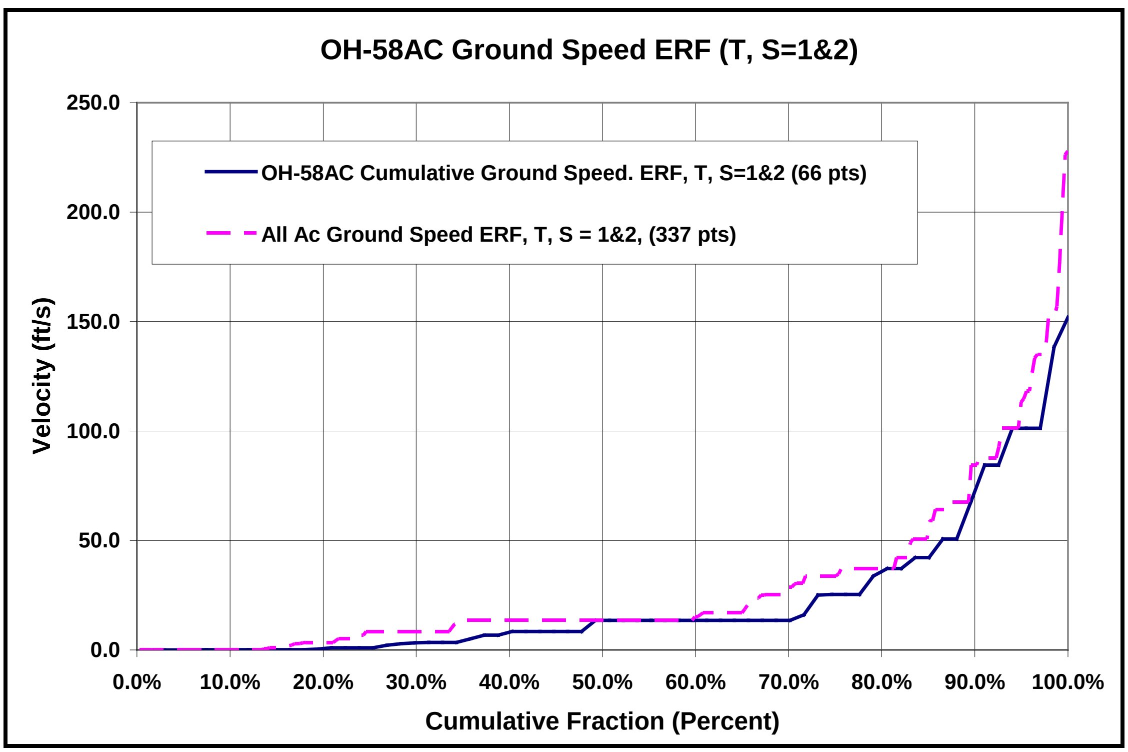

Figure A-42 – OH-58AC Ground Speed ERF (T, S=1&2)

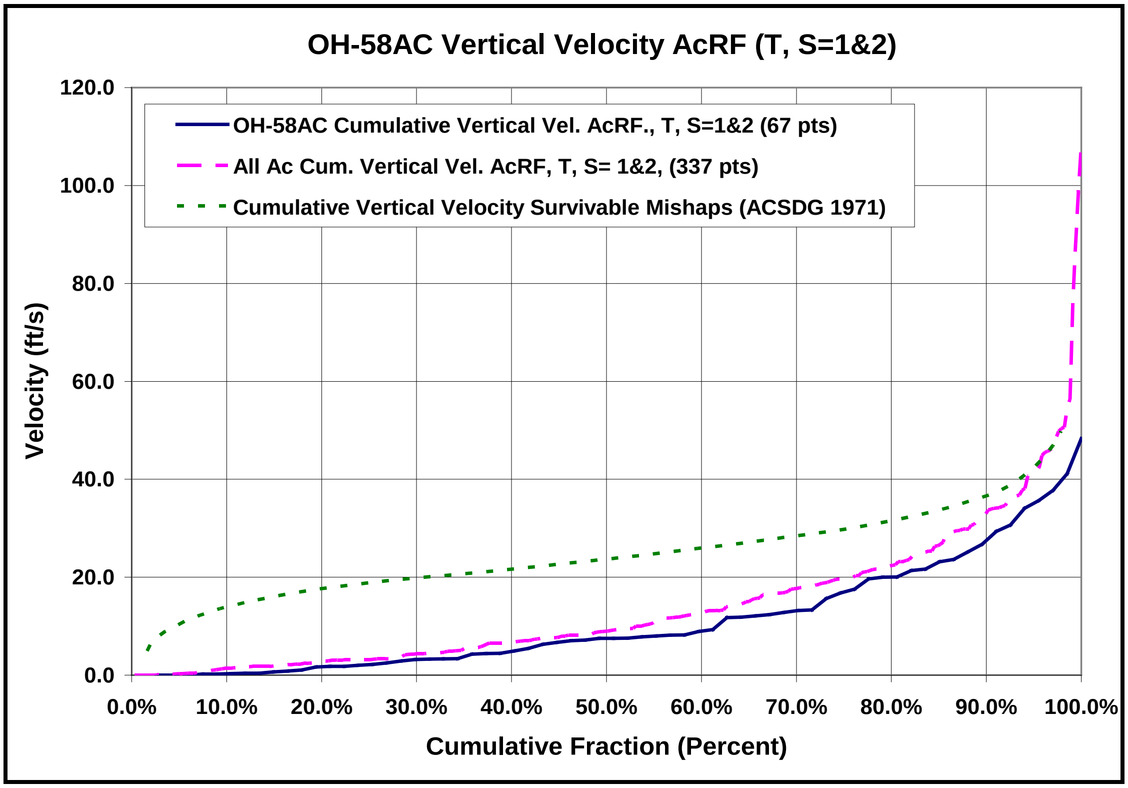

Figure A-43 – OH-58AC Vertical Velocity AcRF (T, S=1&2)

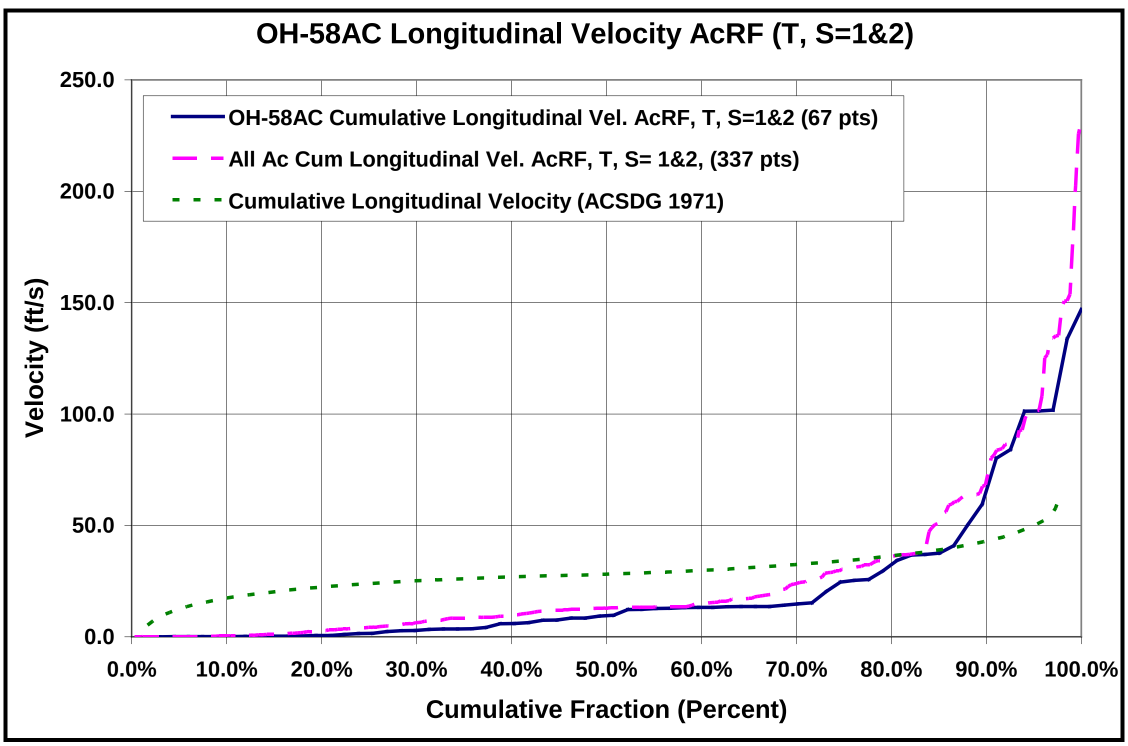

Figure A-44 – OH-58AC Longitudinal Velocity AcRF (T, S=1&2)

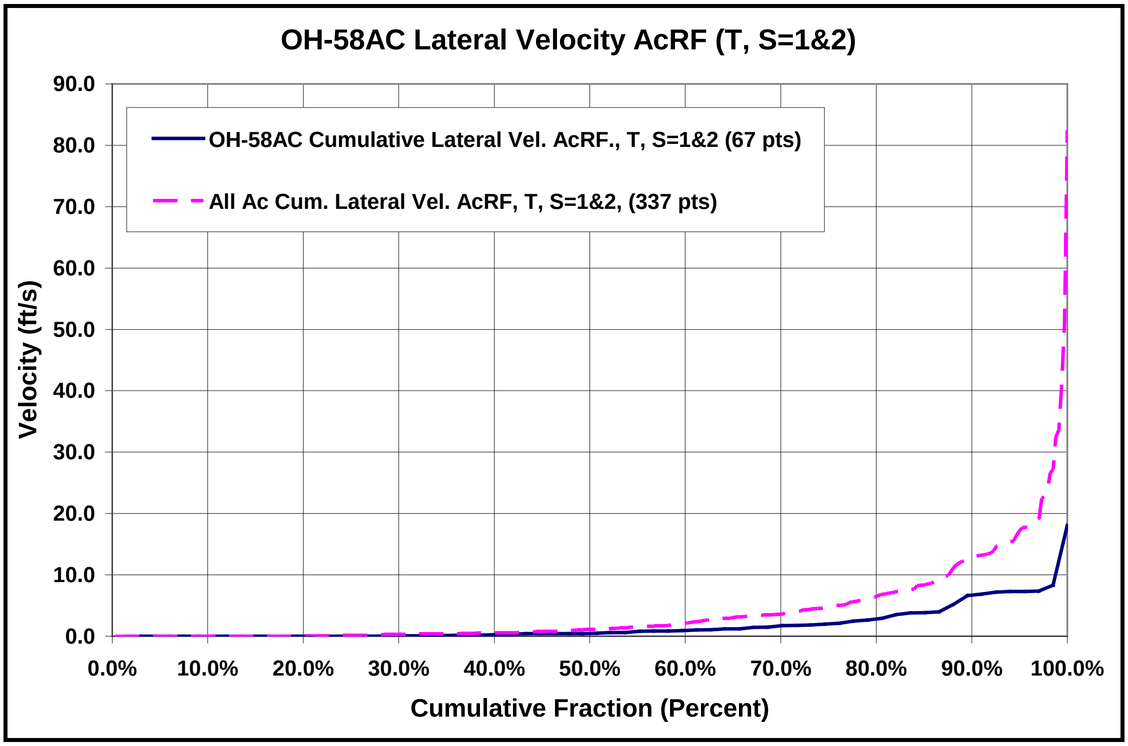

Figure A-45 – OH-58AC Lateral Velocity AcRF (T, S=1&2)

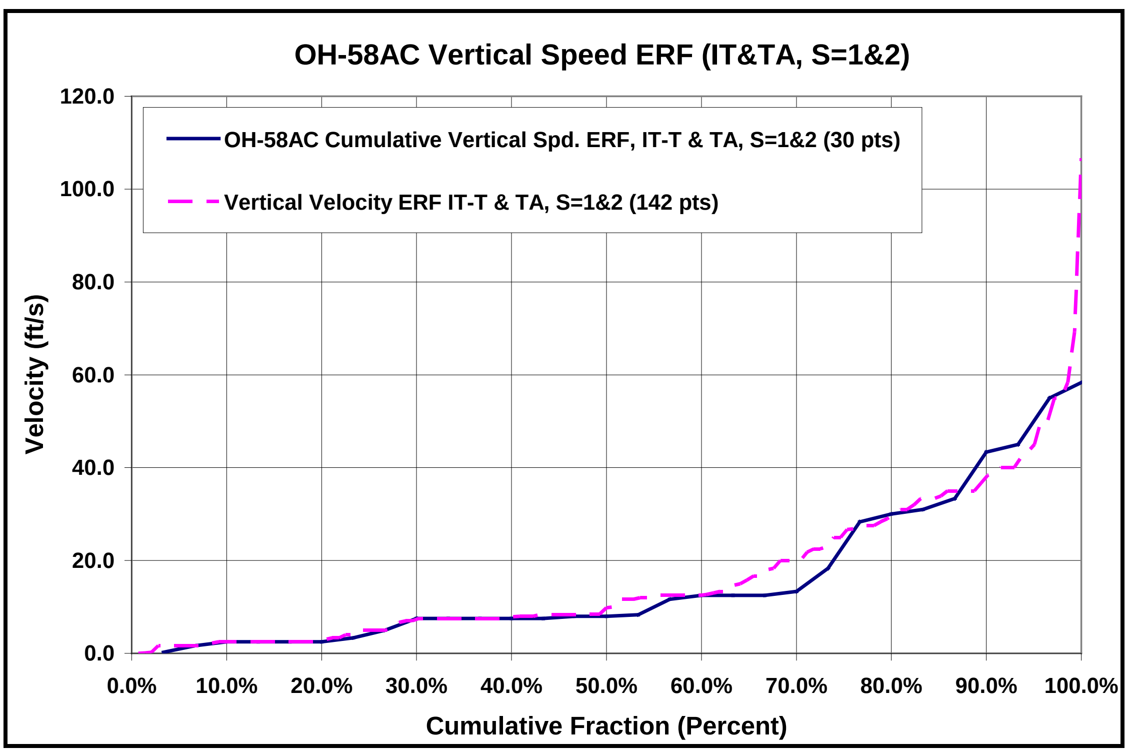

Figure A-46 – OH-58AC Vertical Speed ERF (IT&TA, S=1&2)

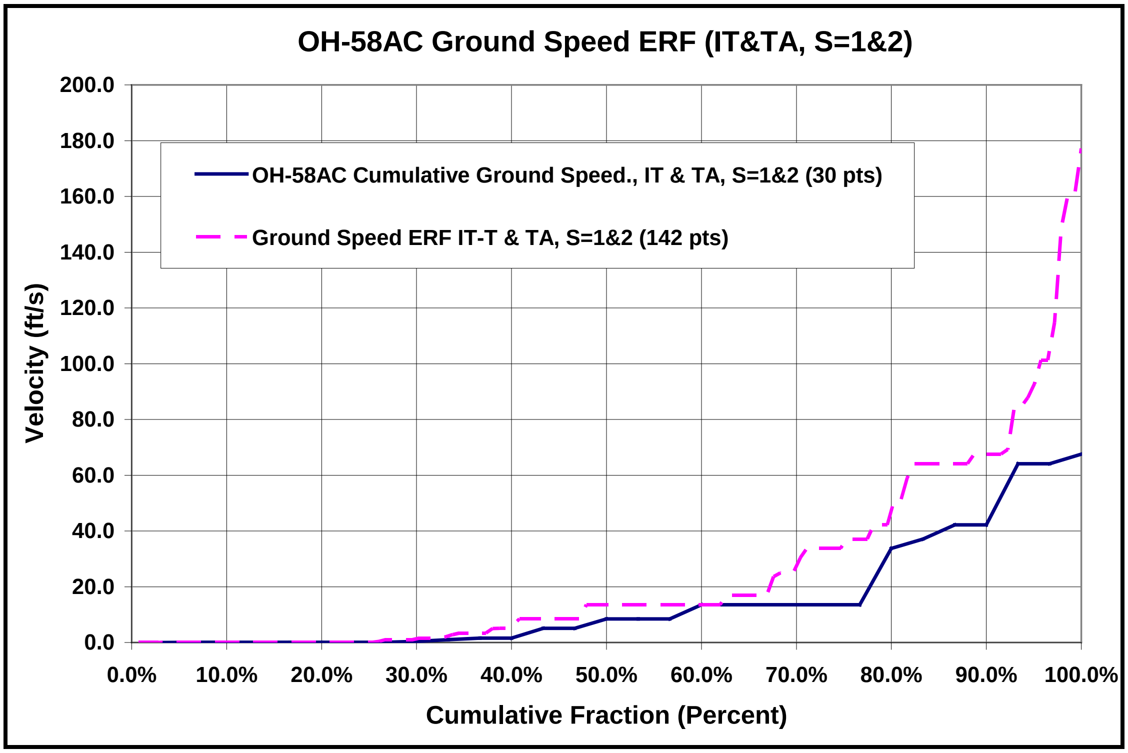

Figure A-47 – OH-58AC Ground Speed ERF (IT&TA, S=1&2)

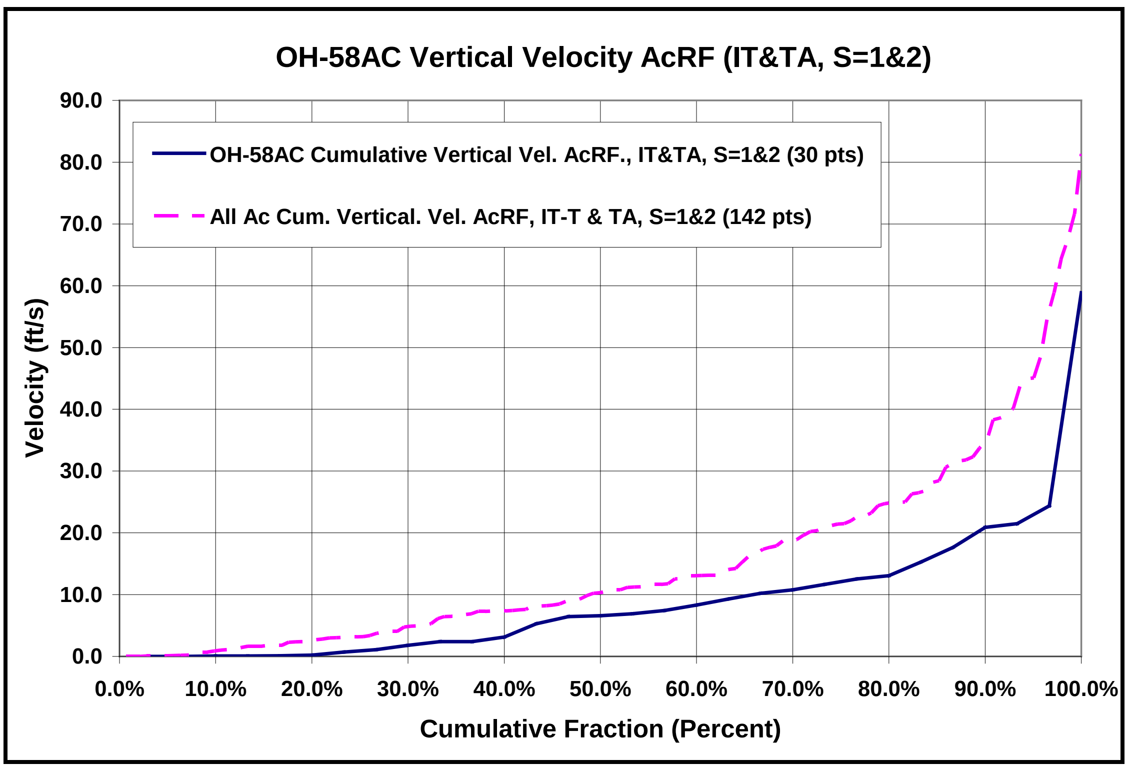

Figure A-48 – OH-58AC Vertical Velocity AcRF (IT&TA, S=1&2)

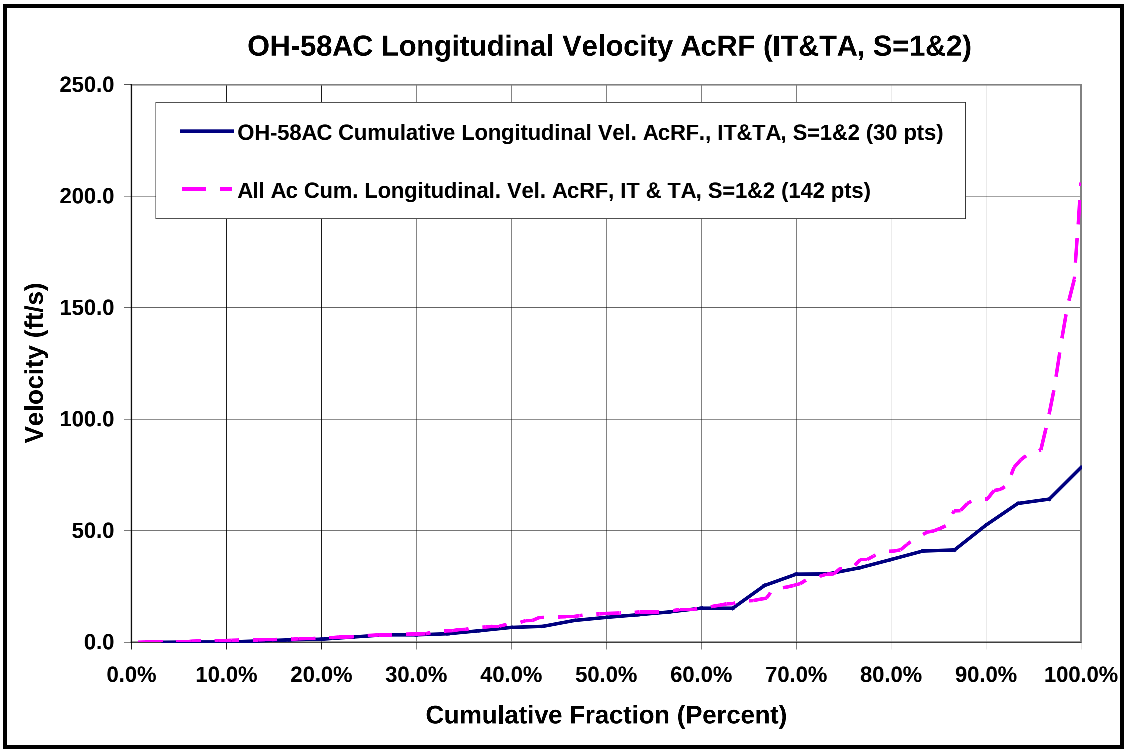

Figure A-49 – OH-58AC Longitudinal Velocity AcRF (IT&TA, S=1&2)

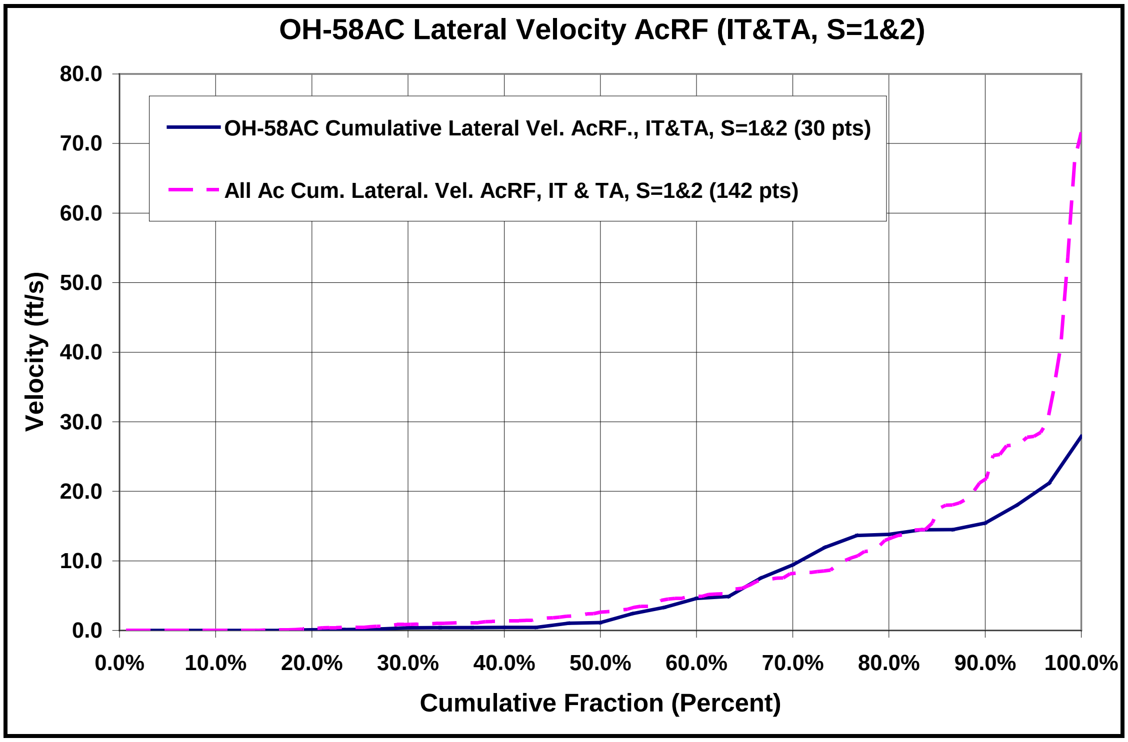

Figure A-50 – OH-58AC Lateral Velocity AcRF (IT&TA, S=1&2)

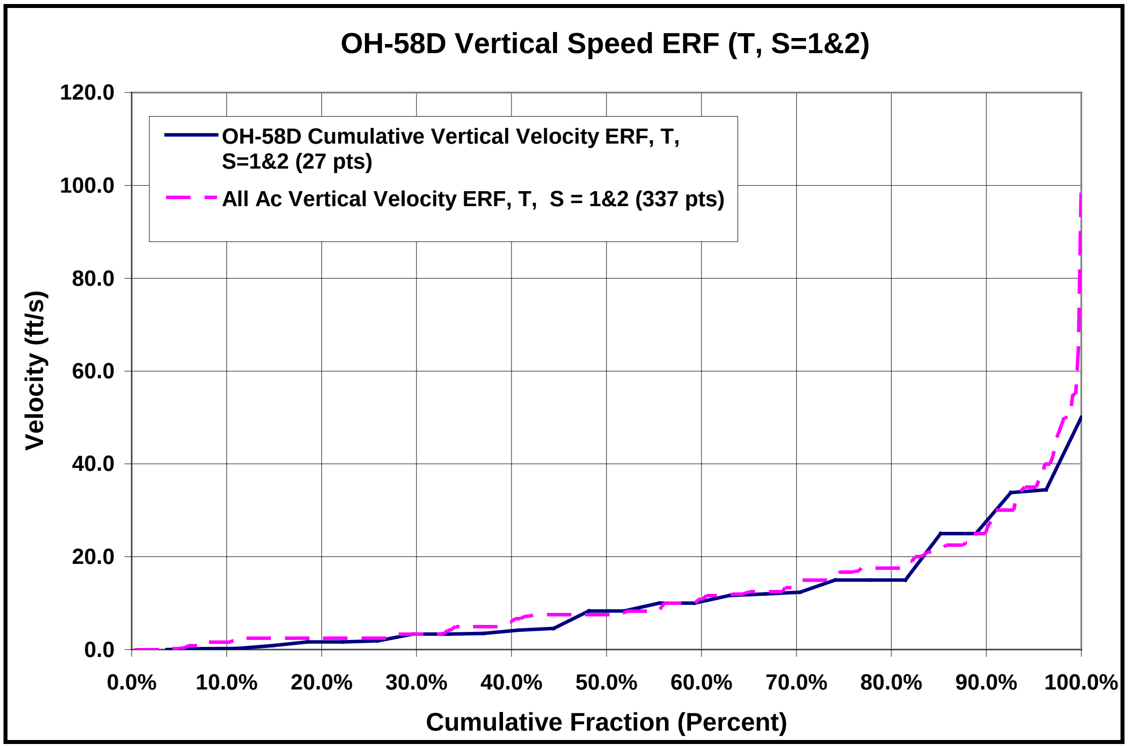

Figure A-51 – OH-58D Vertical Speed ERF (T, S=1&2)

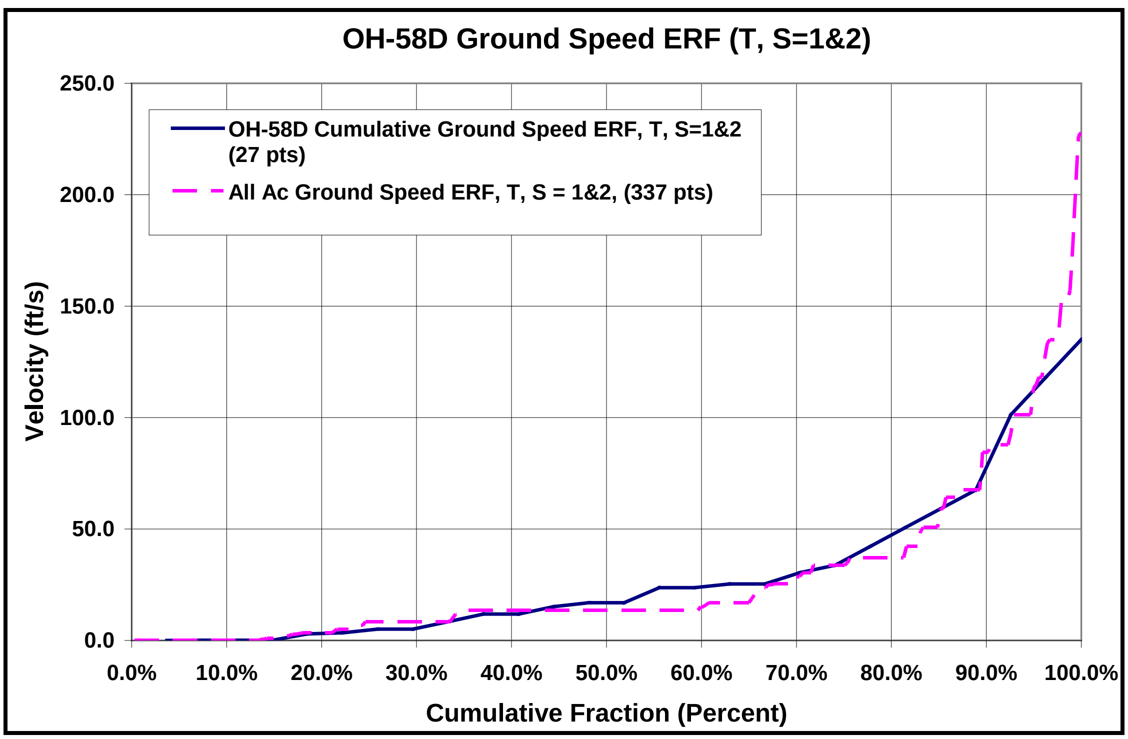

Figure A-52 – OH-58D Ground Speed ERF (T, S=1&2)

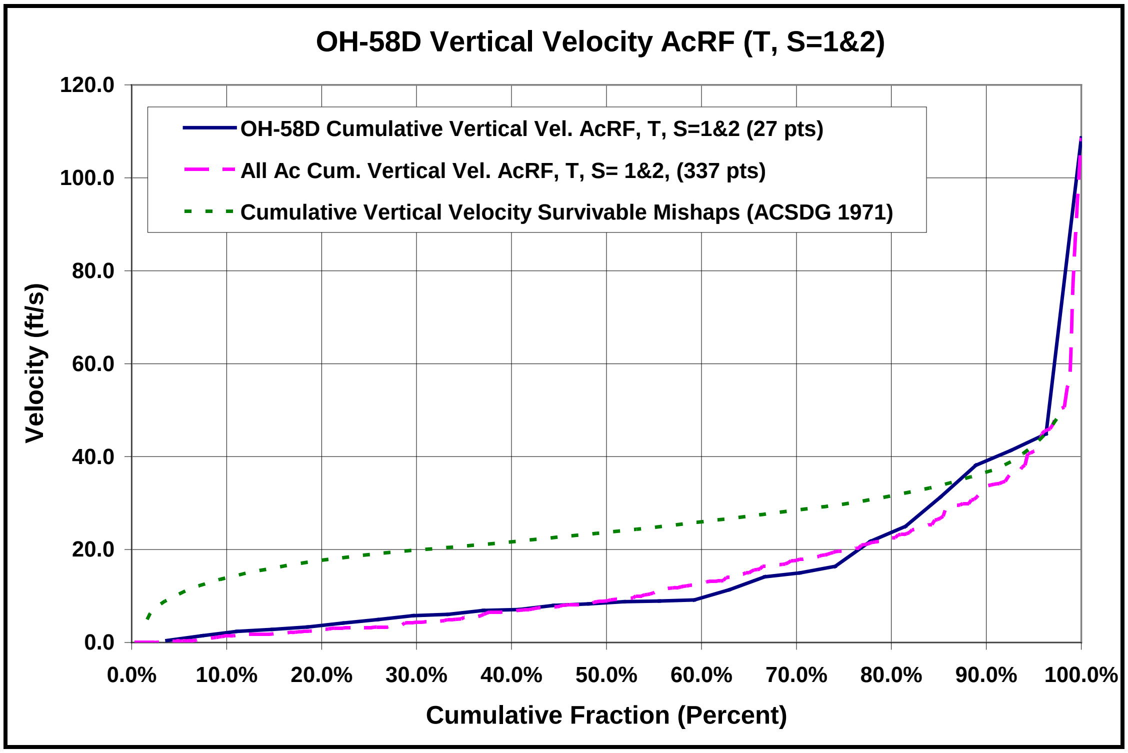

Figure A-53 – OH-58D Vertical Velocity AcRF (T, S=1&2)

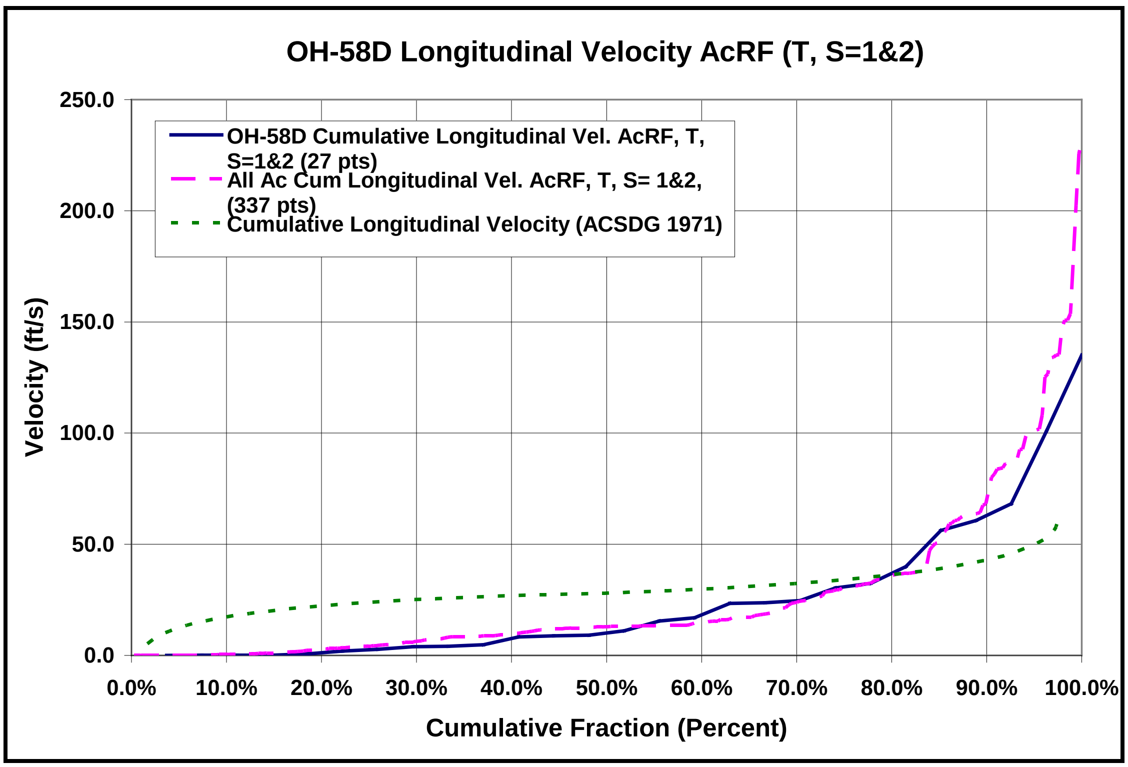

Figure A-54 – OH-58D Longitudinal Velocity AcRF (T, S=1&2)

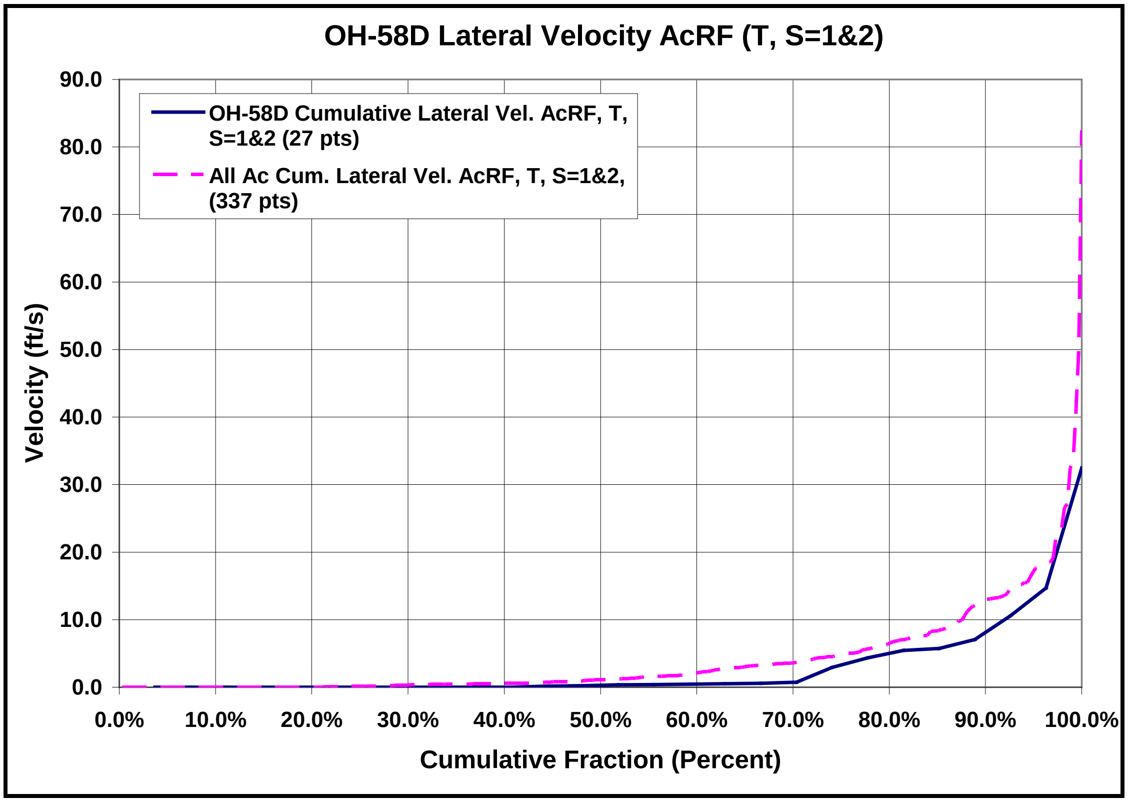

Figure A-55 – OH-58D Lateral Velocity AcRF (T, S=1&2)

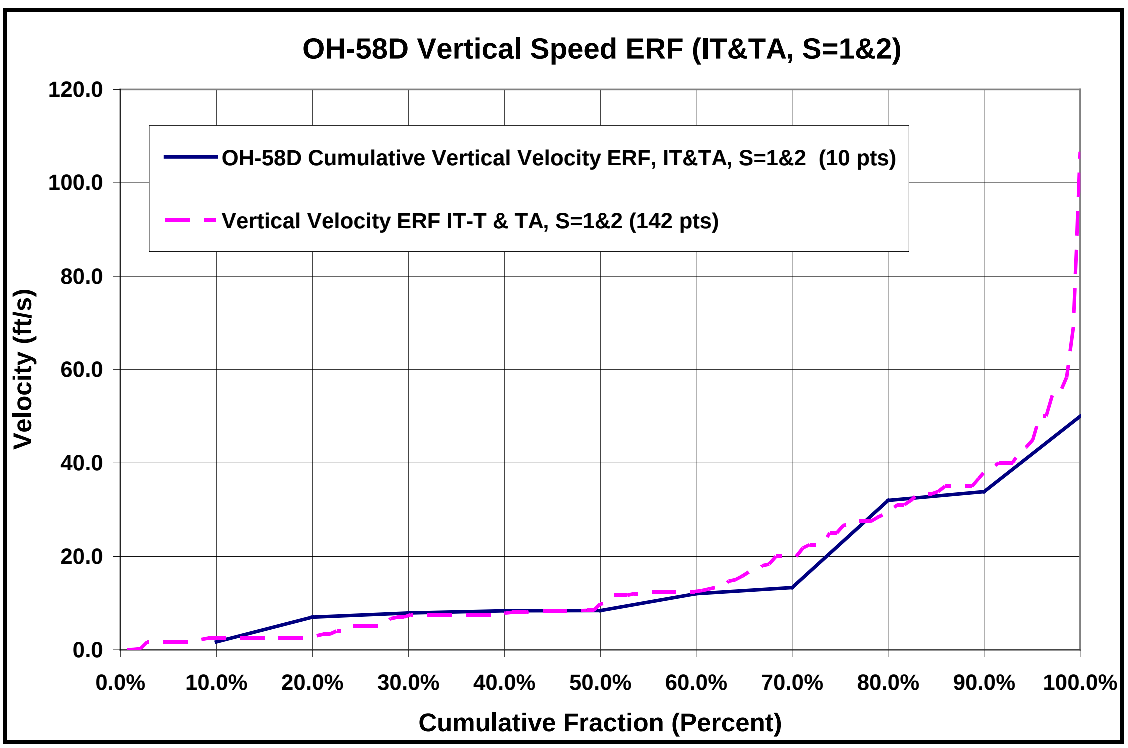

Figure A-56 – OH-58D Vertical Speed ERF (IT&TA, S=1&2)

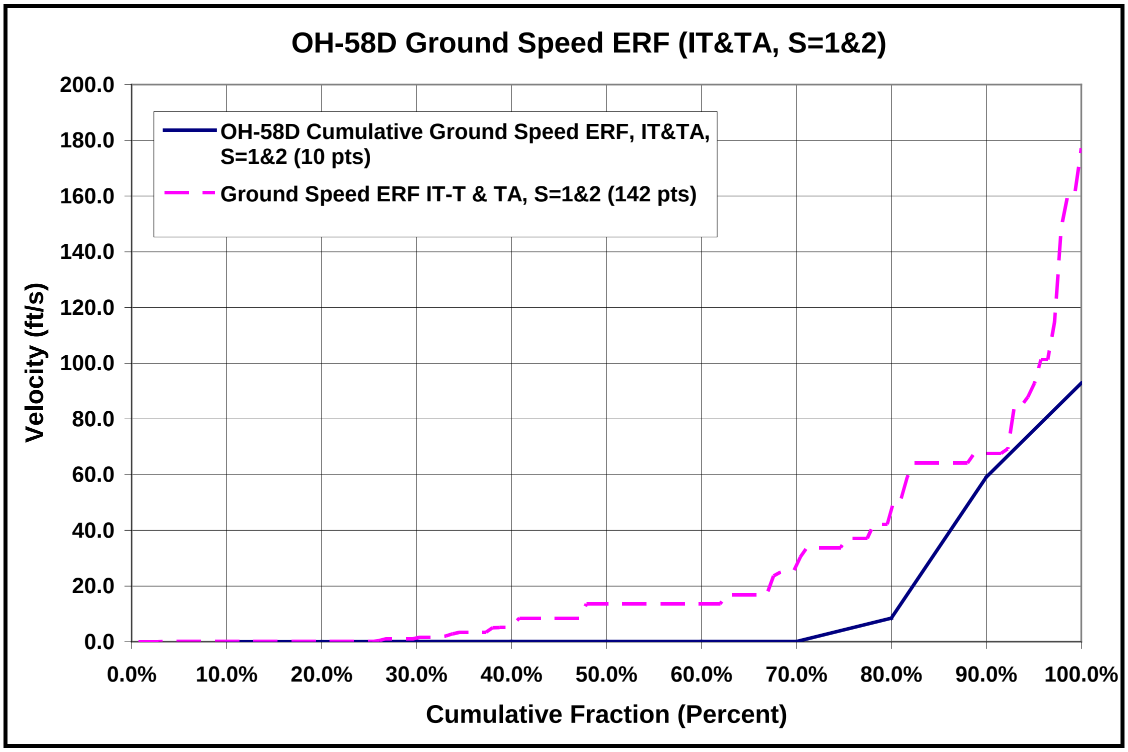

Figure A-57 – OH-58D Ground Speed ERF (IT&TA, S=1&2)

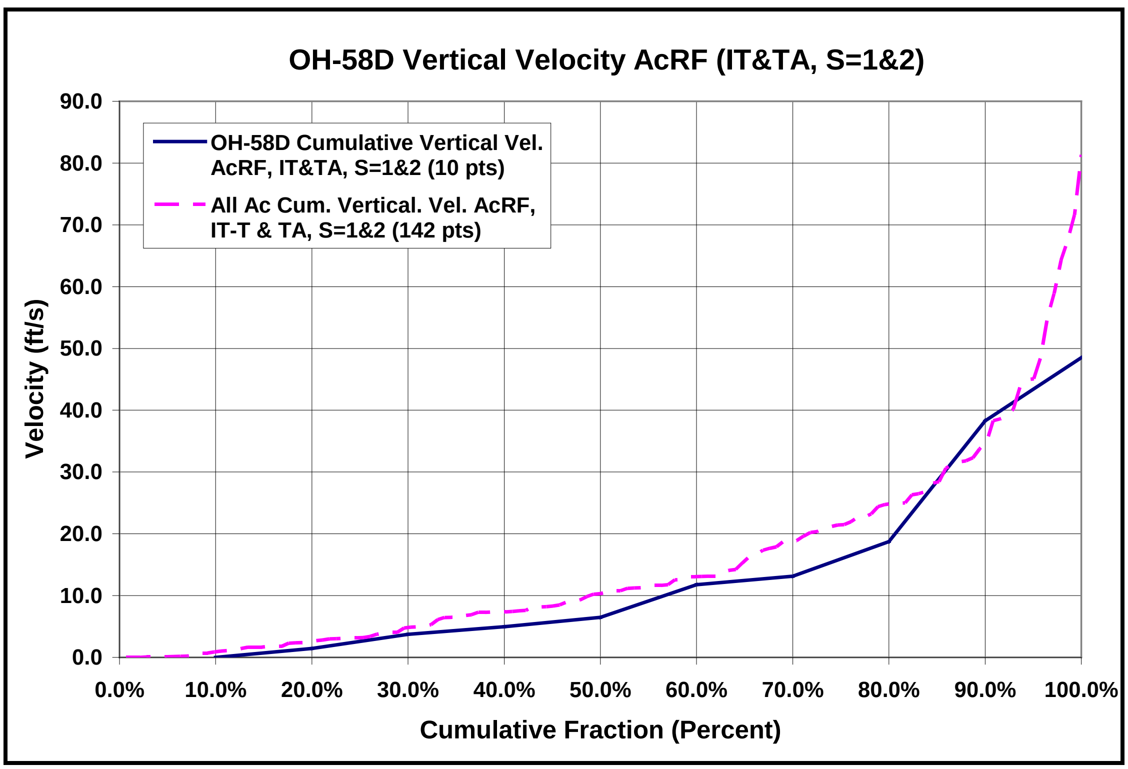

Figure A-58 – OH-58D Vertical Velocity AcRF (IT&TA, S=1&2)

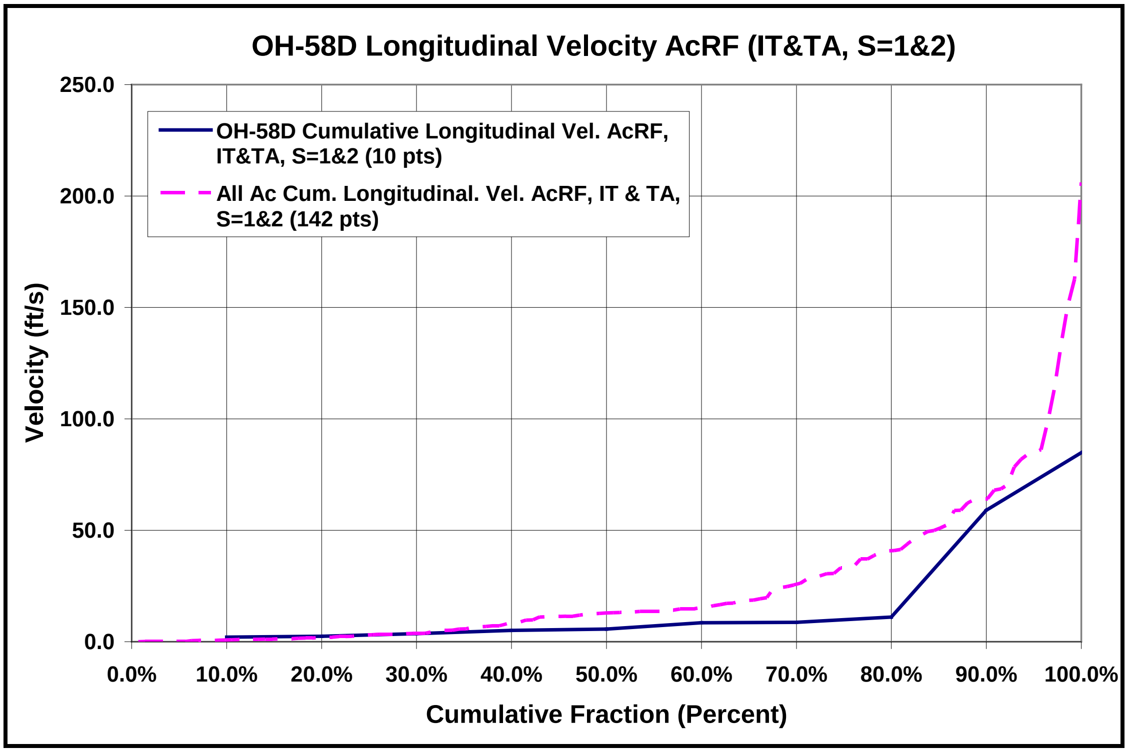

Figure A-59 – OH-58D Longitudinal Velocity AcRF (IT&TA, S=1&2)

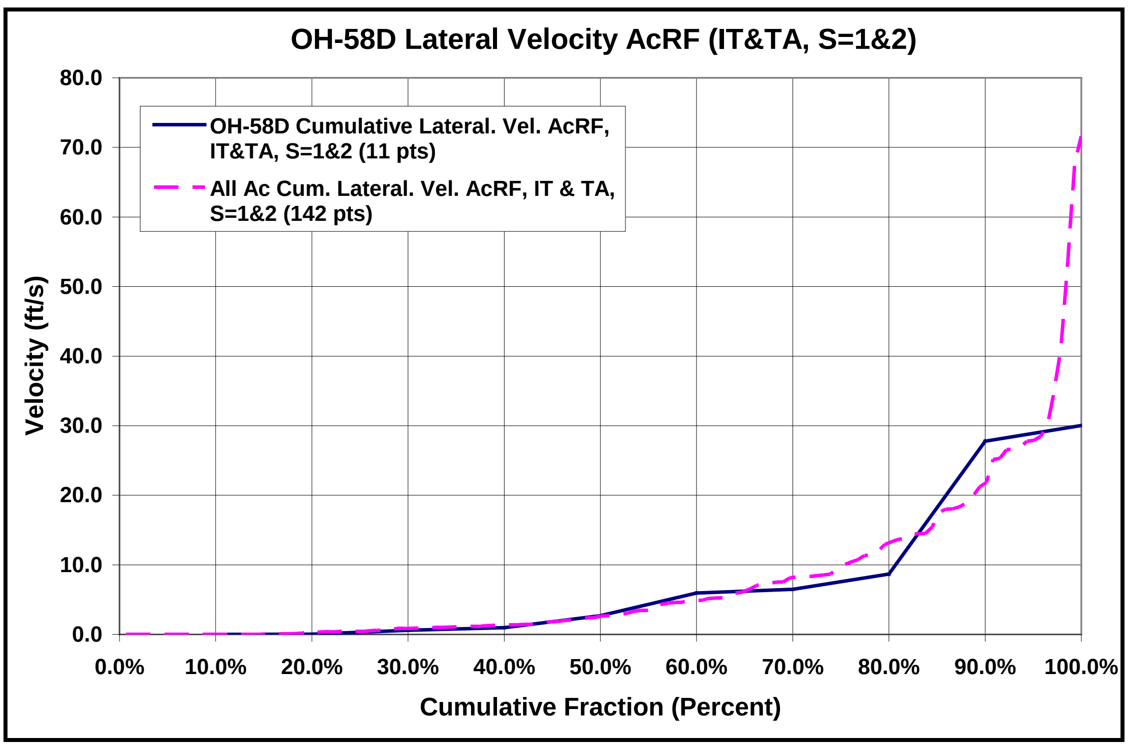

Figure A-60 – OH-58D Lateral Velocity AcRF (IT&TA, S=1&2)

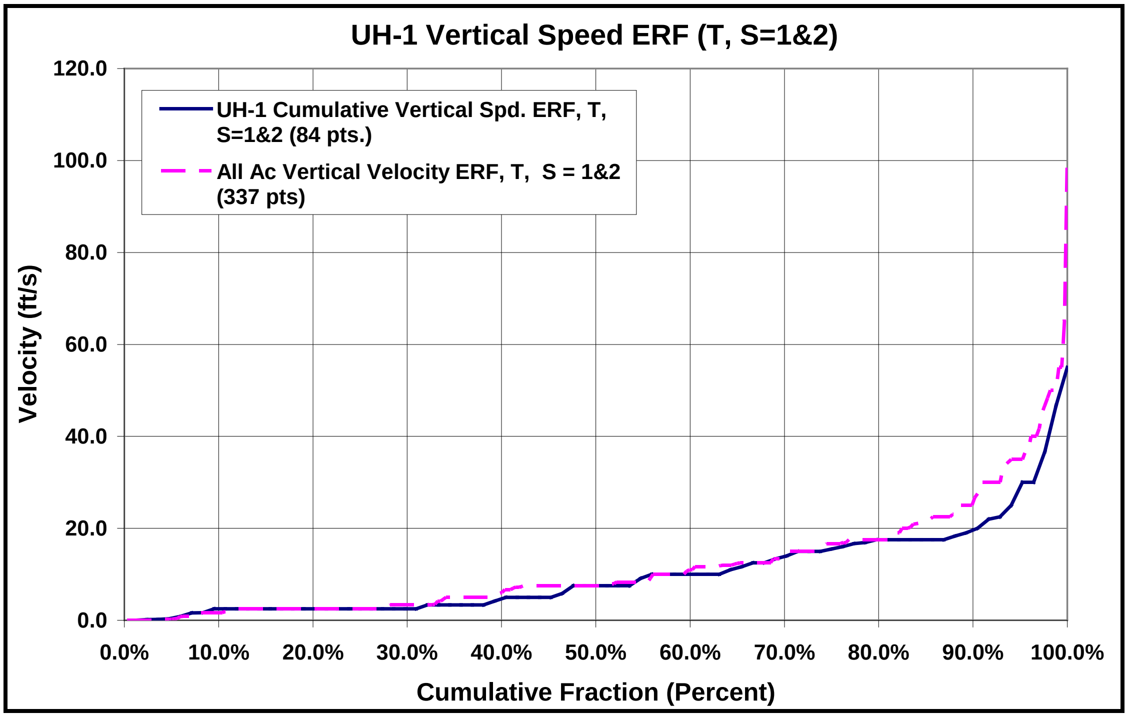

Figure A-61 – UH-1 Vertical Speed ERF (T, S=1&2)

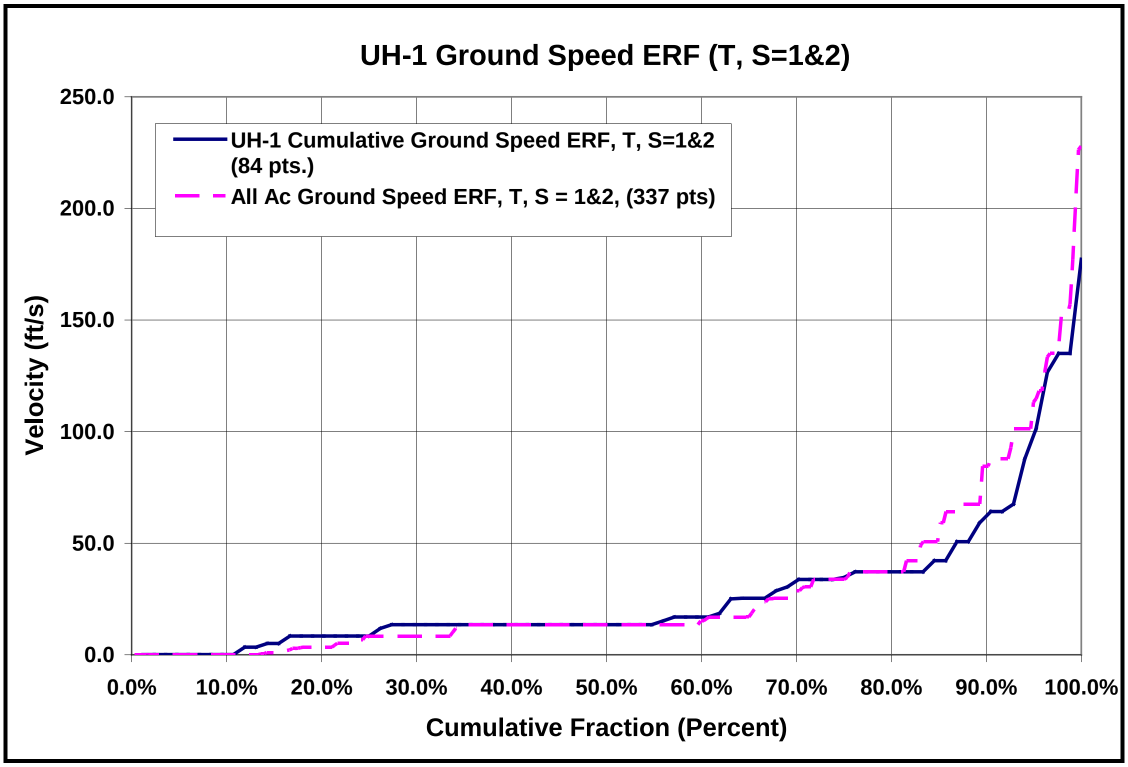

Figure A-62 – UH-1 Ground Speed ERF (T, S=1&2)

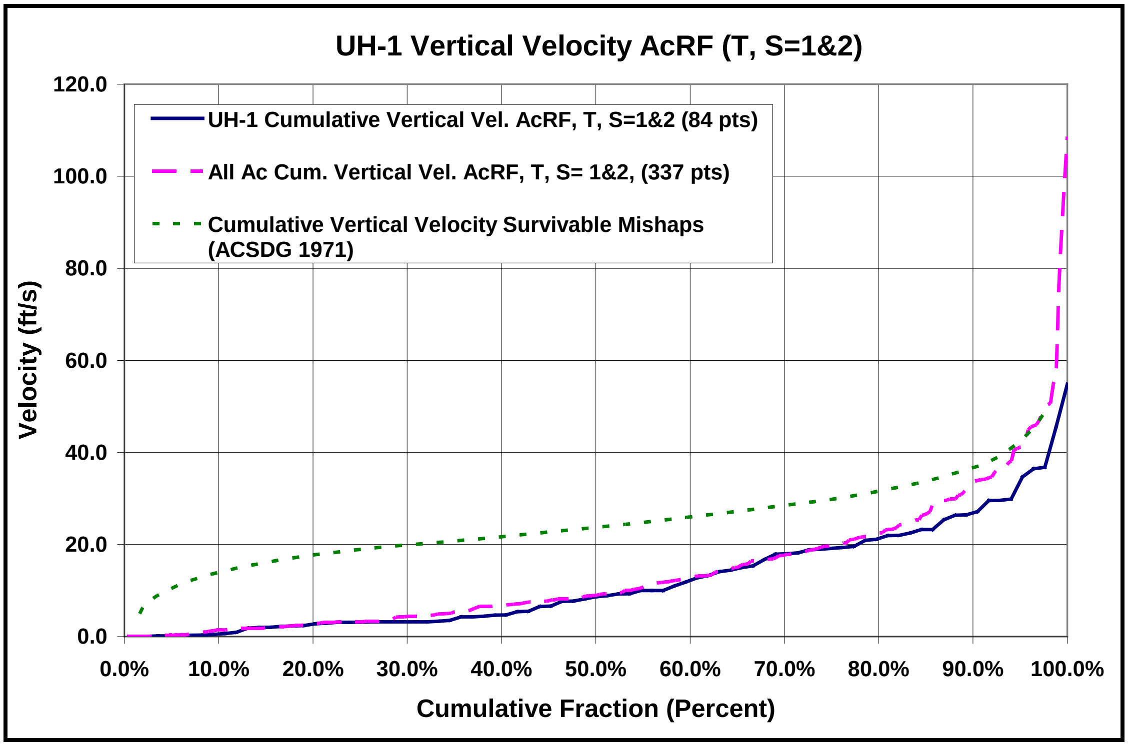

Figure A-63 – UH-1 Vertical Velocity AcRF (T, S=1&2)

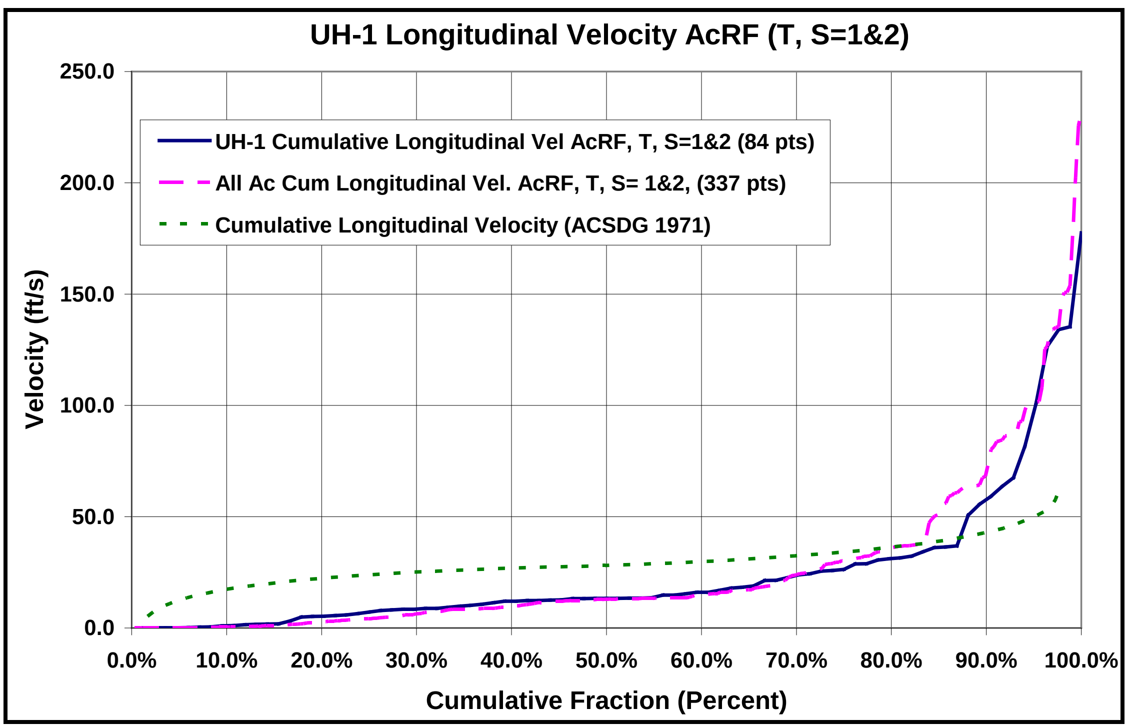

Figure A-64 – UH-1 Longitudinal Velocity AcRF (T, S=1&2)

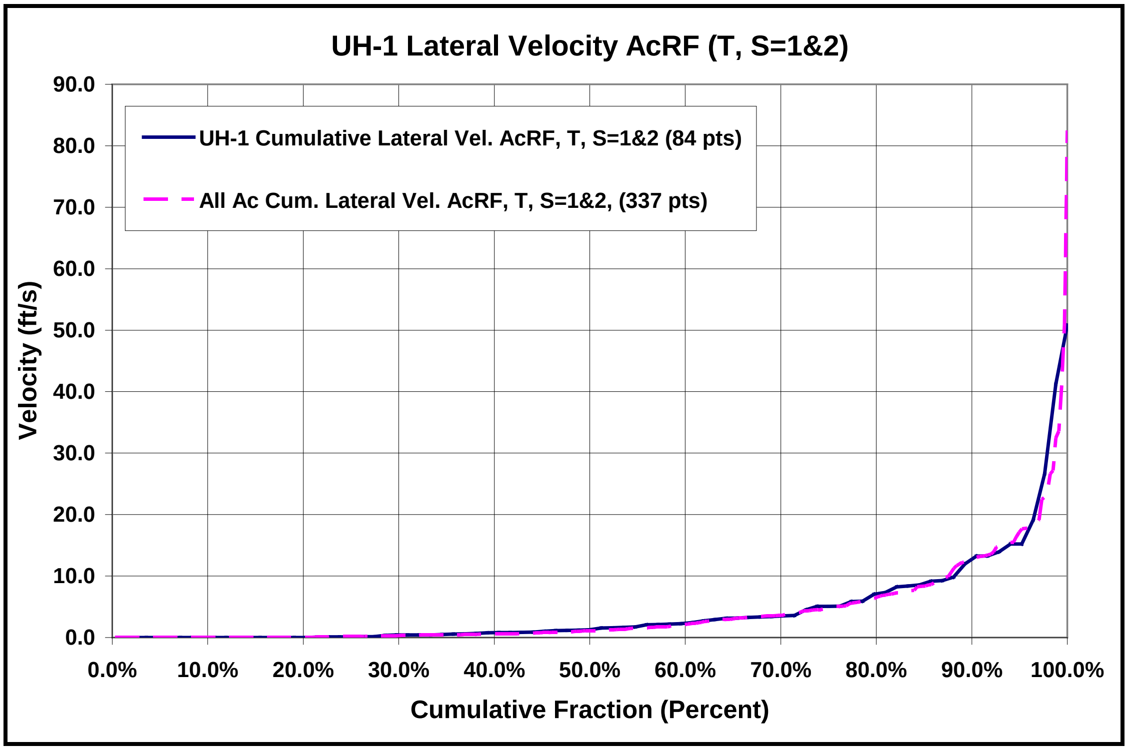

Figure A-65 – UH-1 Lateral Velocity AcRF (T, S=1&2)

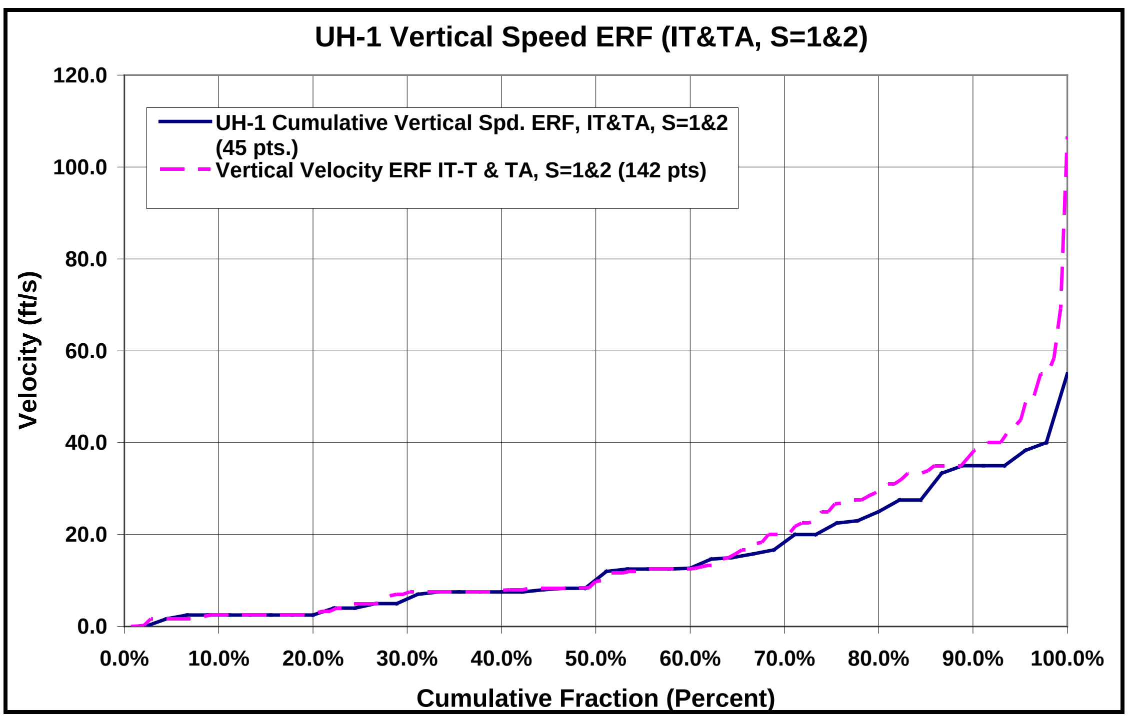

Figure A-66 – UH-1 Vertical Speed ERF (IT&TA, S=1&2)

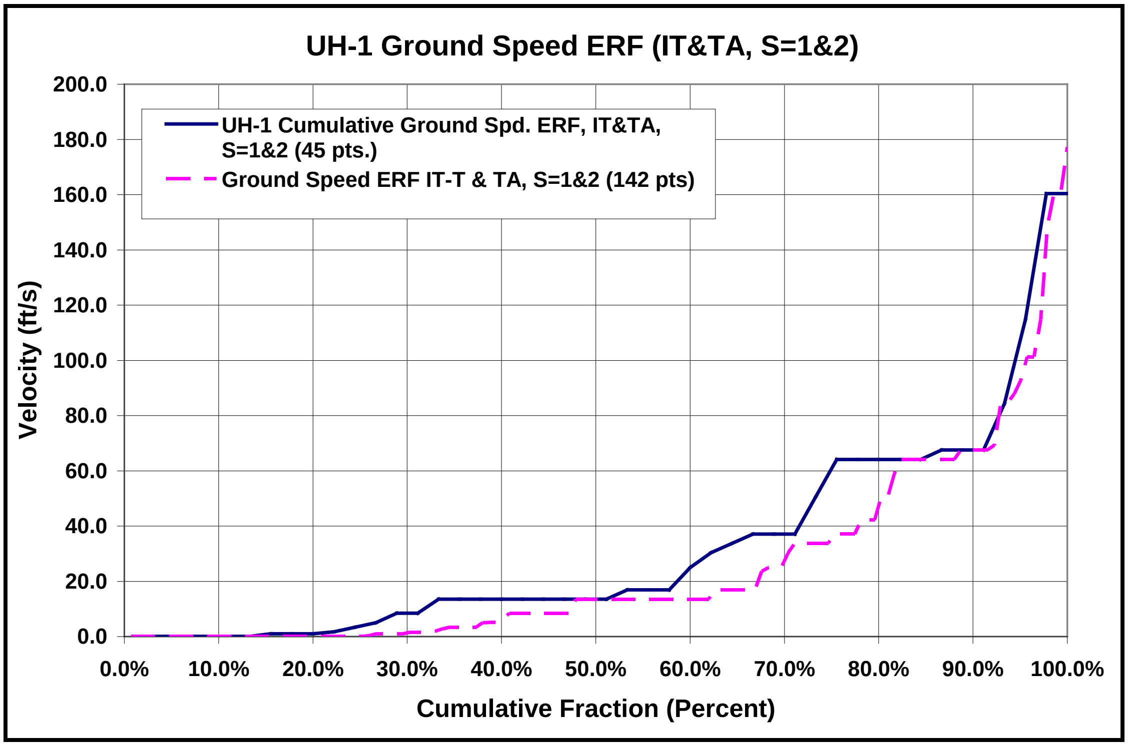

Figure A-67 – UH-1 Ground Speed ERF (IT&TA, S=1&2)

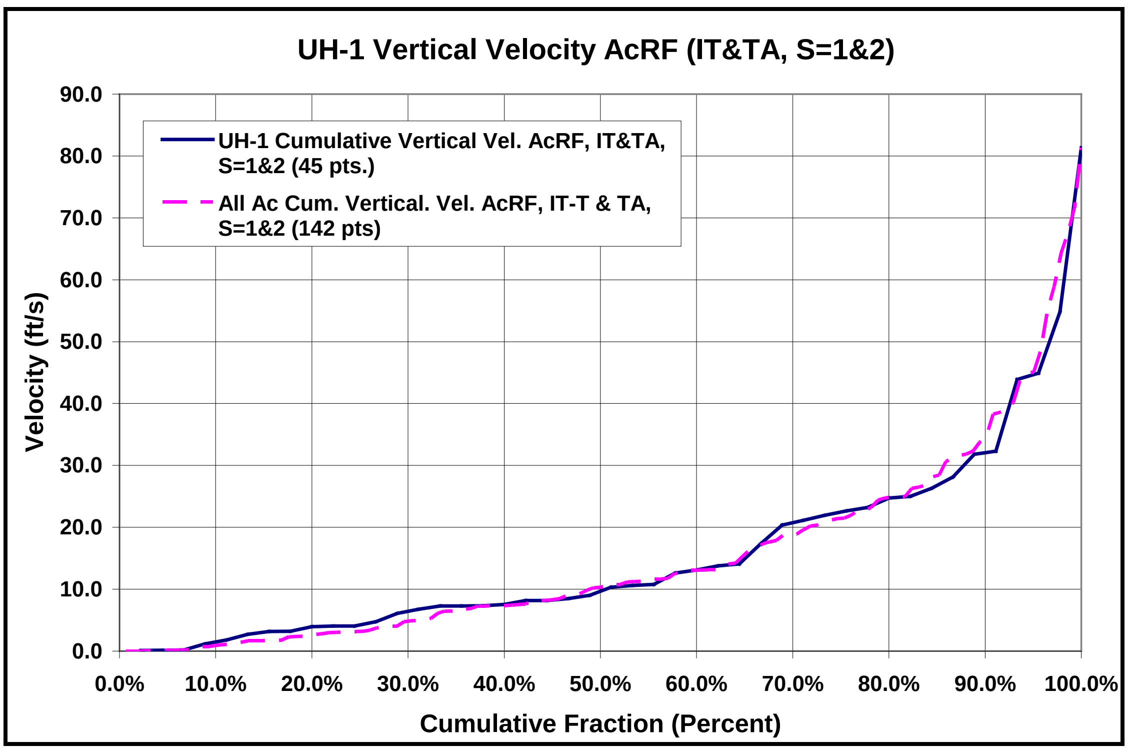

Figure A-68 – UH-1 Vertical Velocity AcRF (IT&TA, S=1&2)

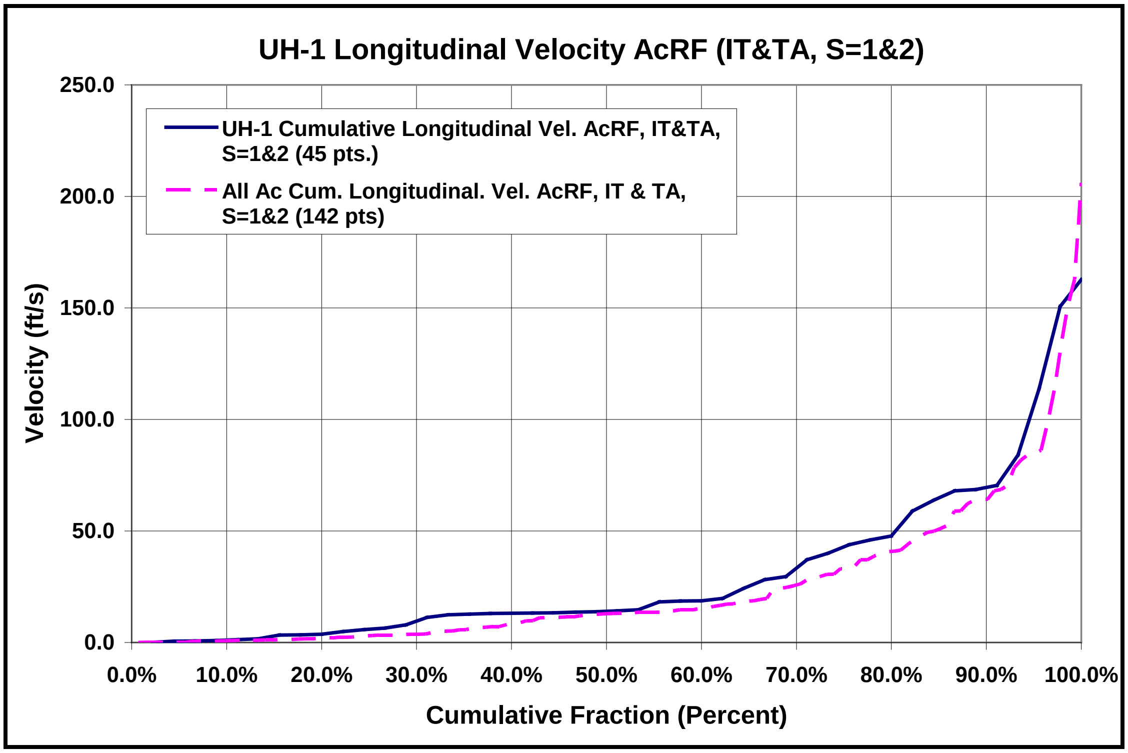

Figure A-69 – UH-1 Longitudinal Velocity AcRF (IT&TA, S=1&2)

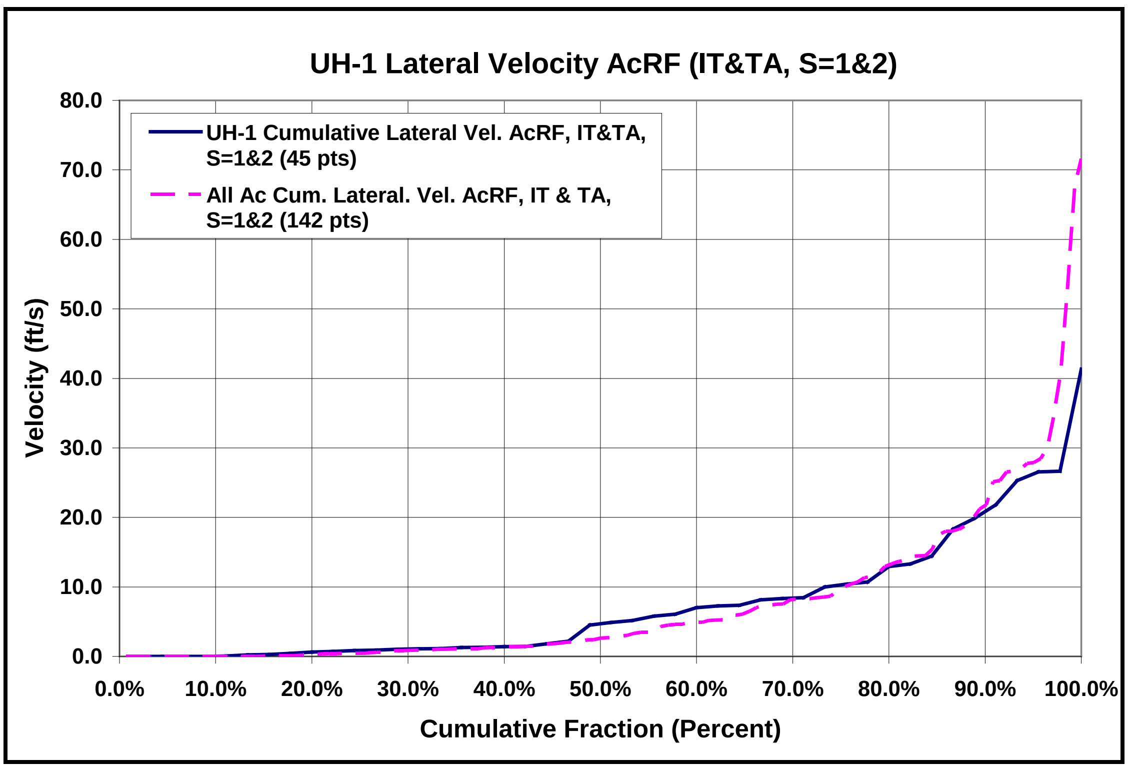

Figure A-70 – UH-1 Lateral Velocity AcRF (IT&TA, S=1&2)

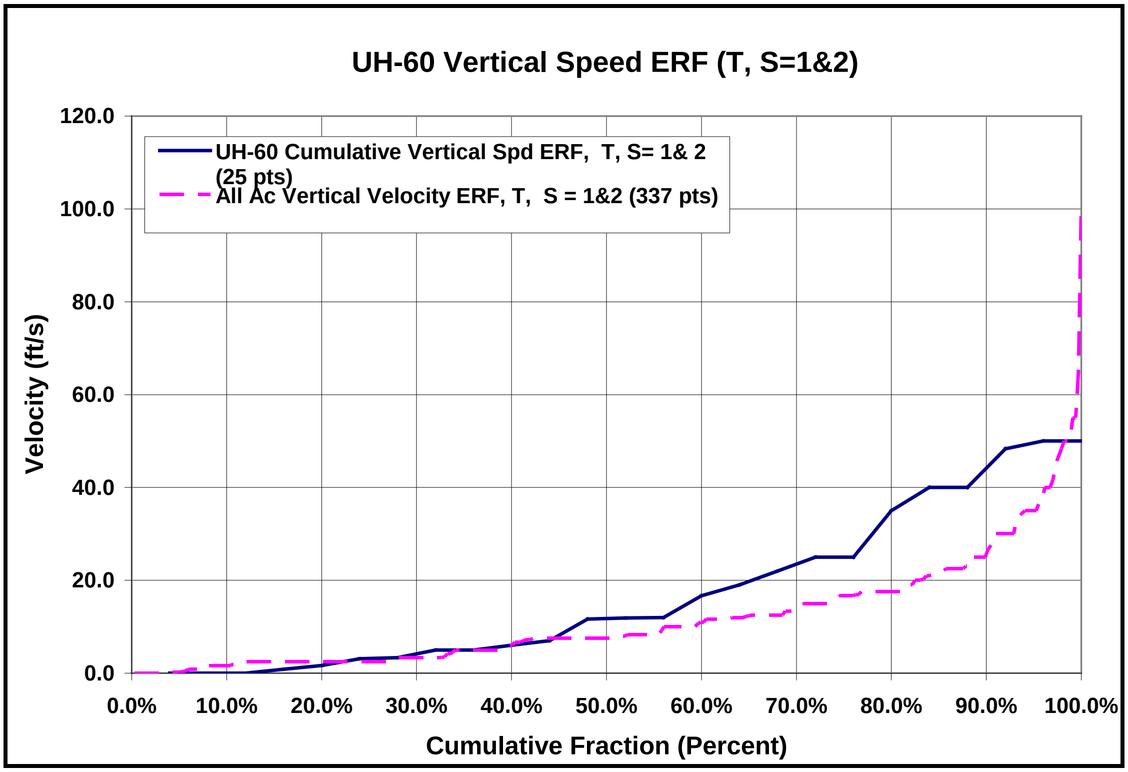

Figure A-71 – UH-60 Vertical Speed ERF (T, S=1&2)

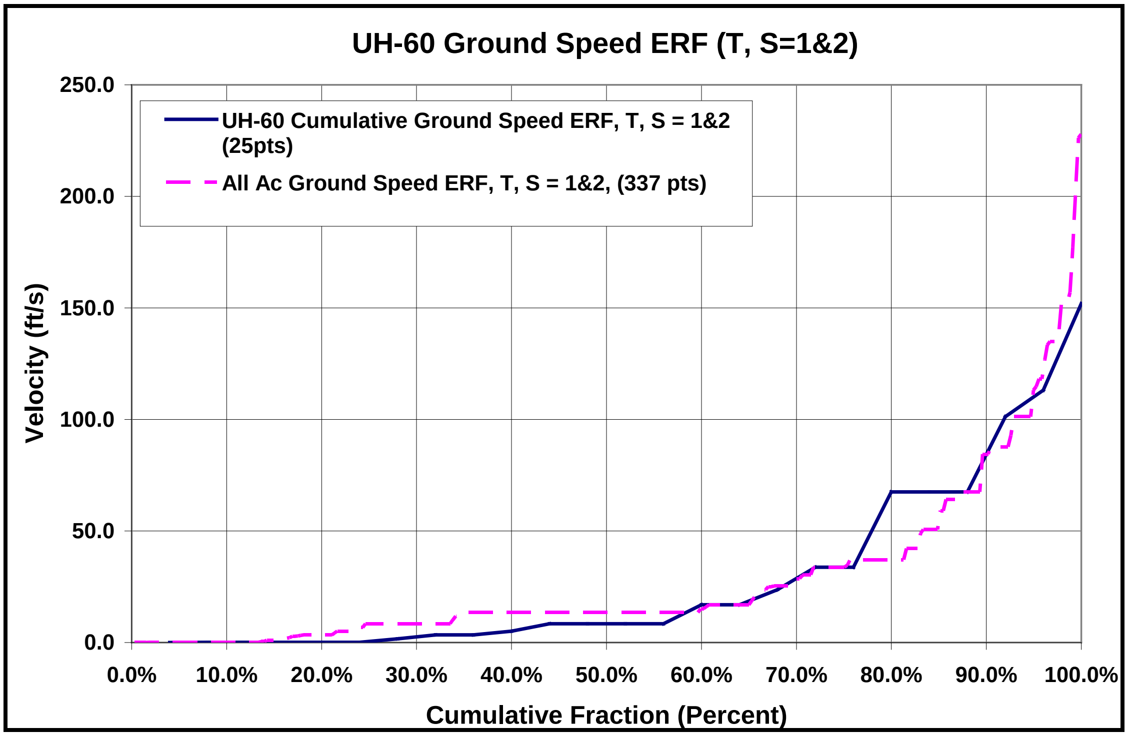

Figure A-72 – UH-60 Ground Speed ERF (T, S=1&2)

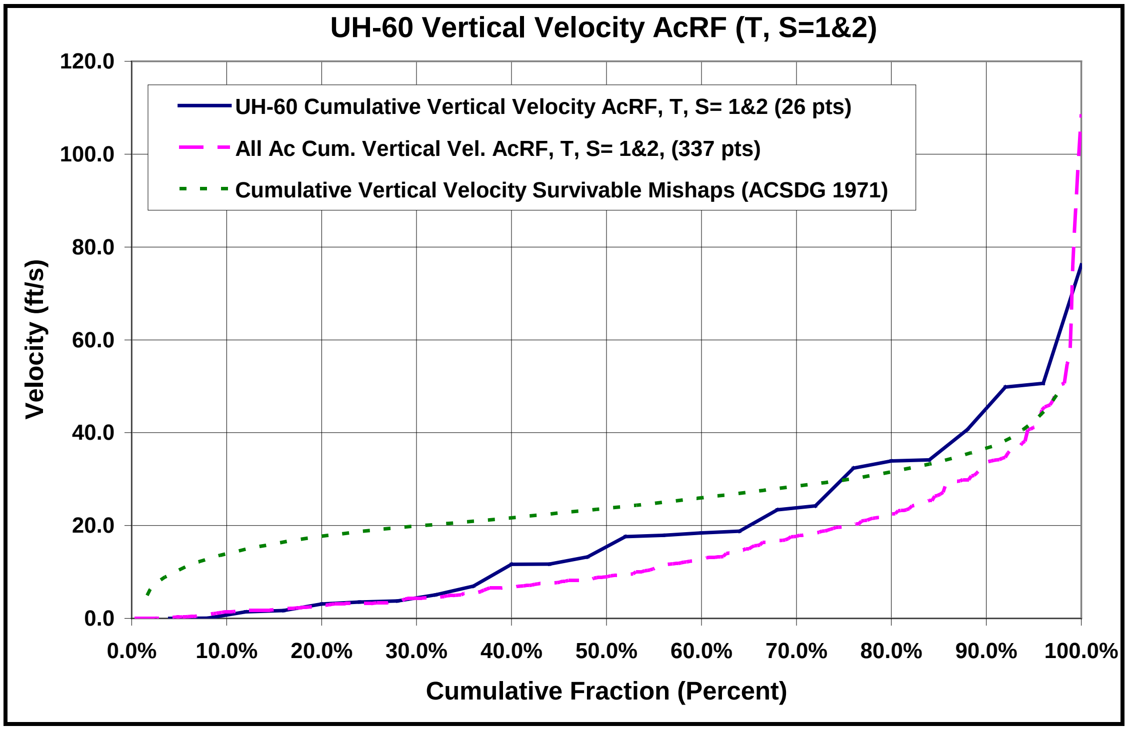

Figure A-73 – UH-60 Vertical Velocity AcRF (T, S=1&2)

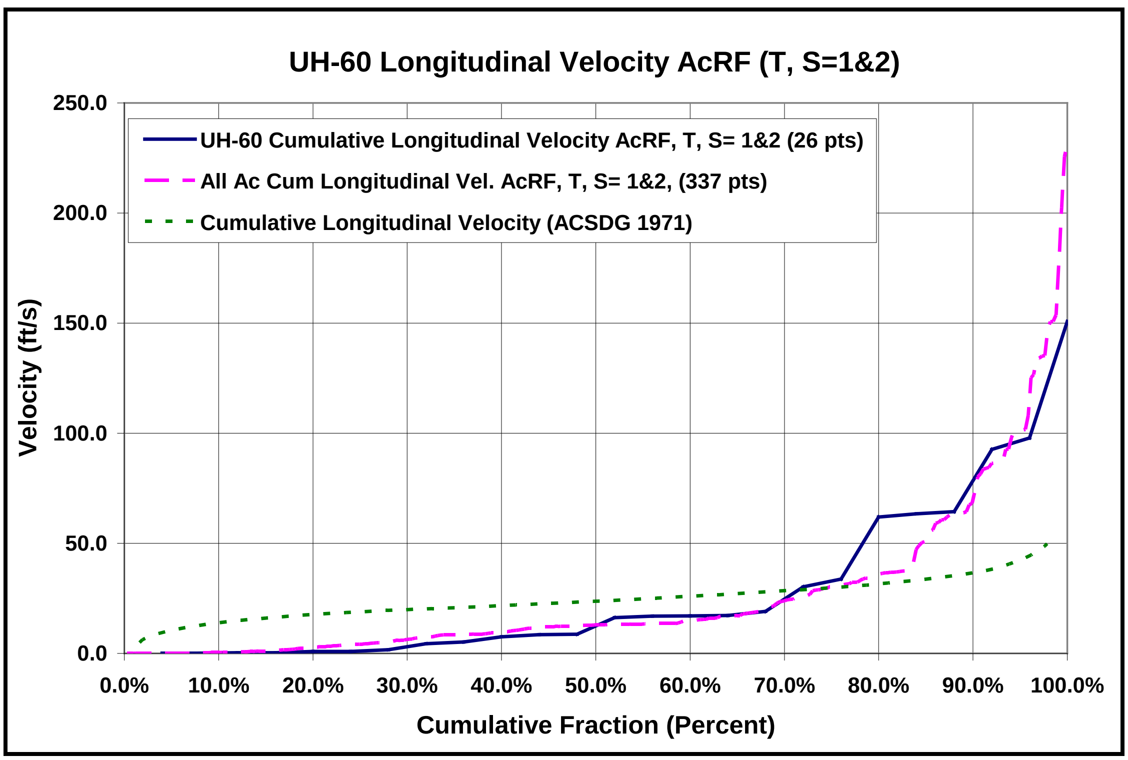

Figure A-74 – UH-60 Longitudinal Velocity AcRF (T, S=1&2)

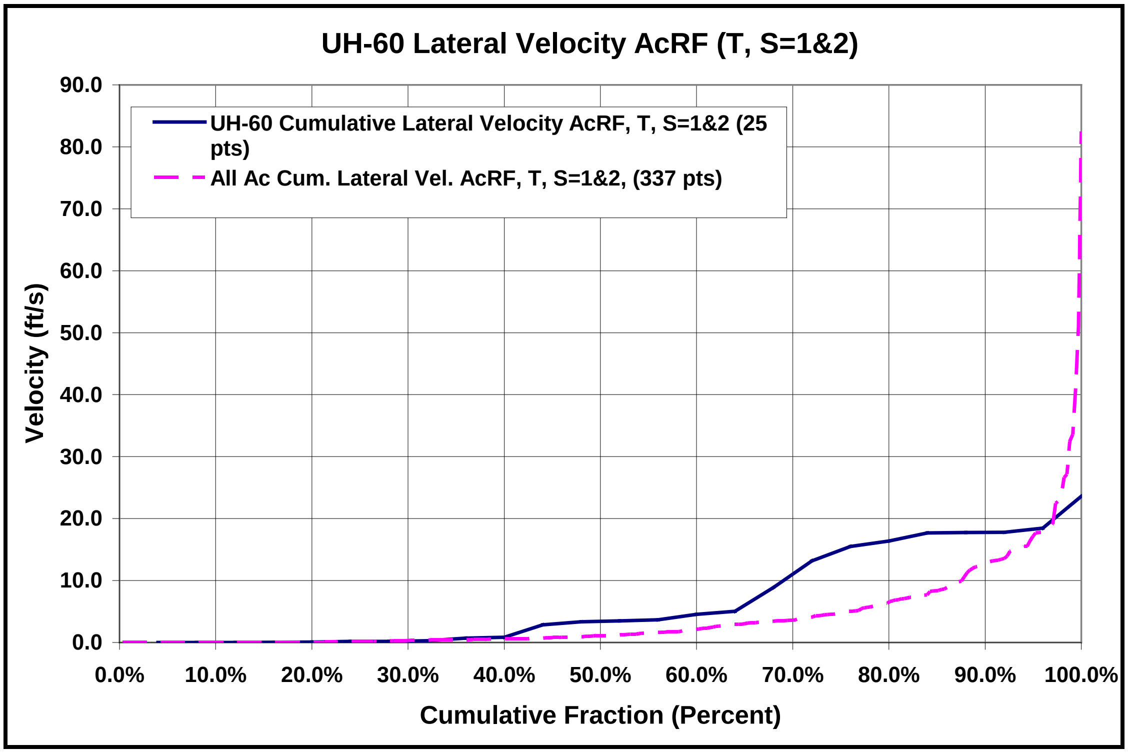

Figure A-75 – UH-60 Lateral Velocity AcRF (T, S=1&2)

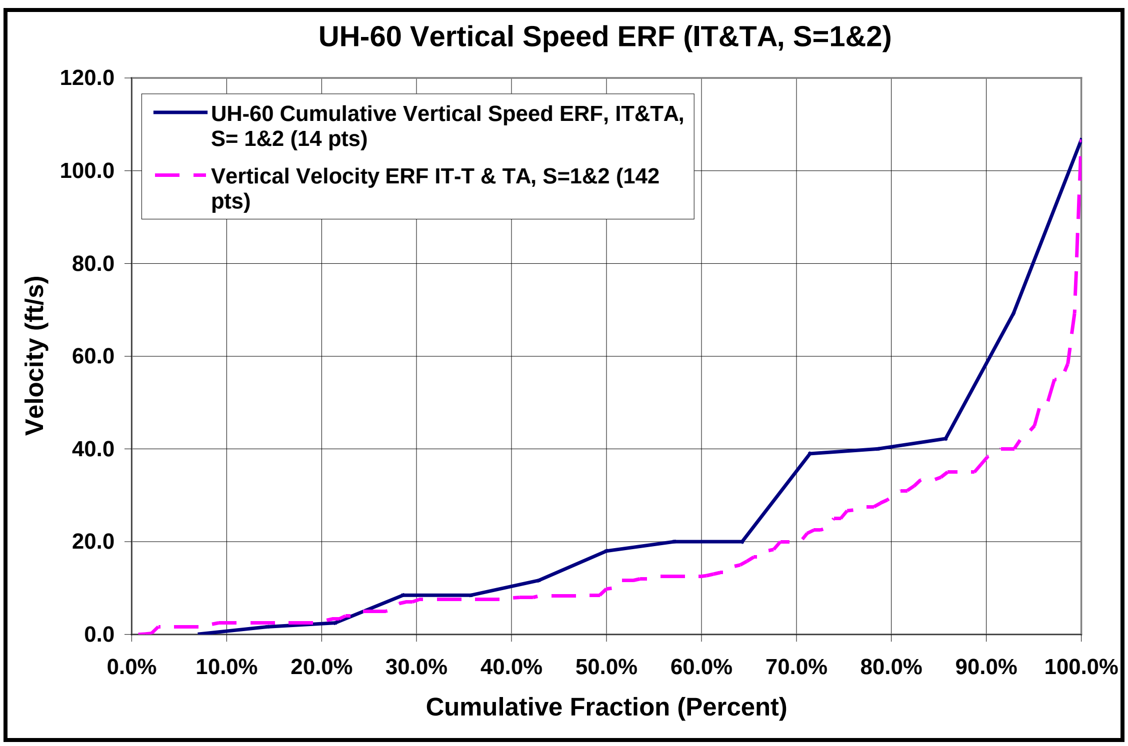

Figure A-76 – UH-60 Vertical Speed ERF (IT&TA, S=1&2)

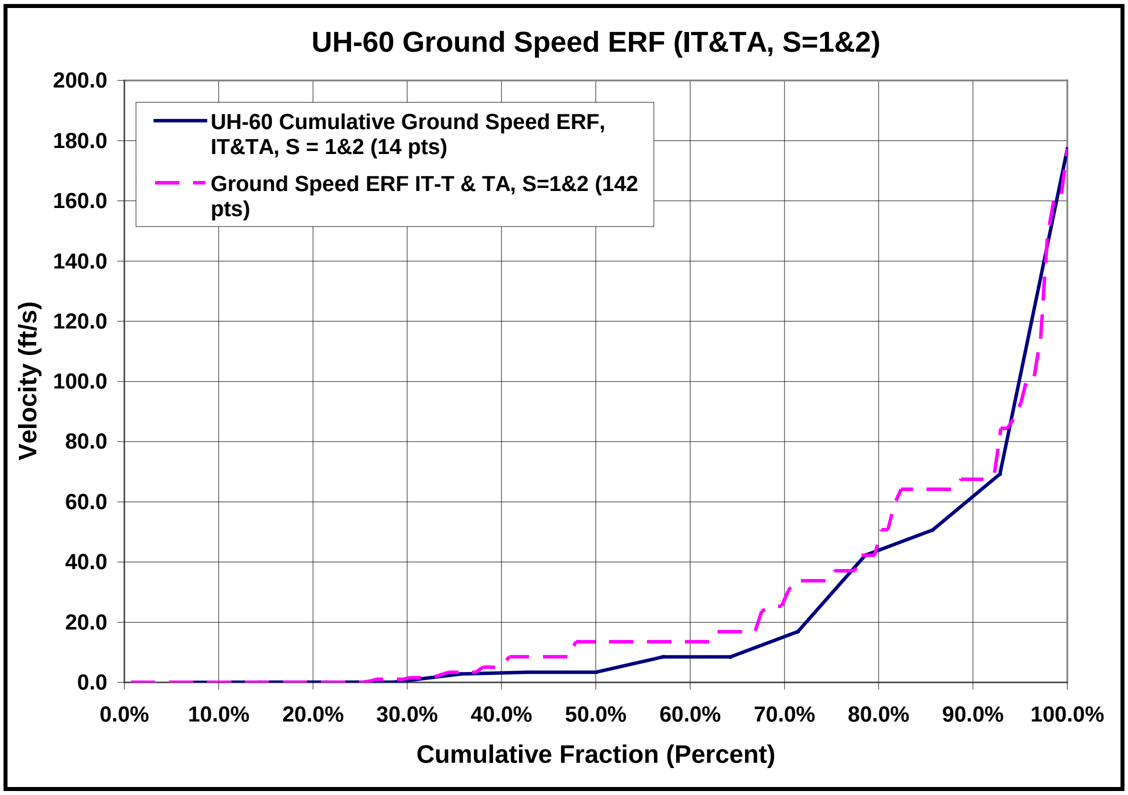

Figure A-77 – UH-60 Ground Speed ERF (IT&TA, S=1&2)

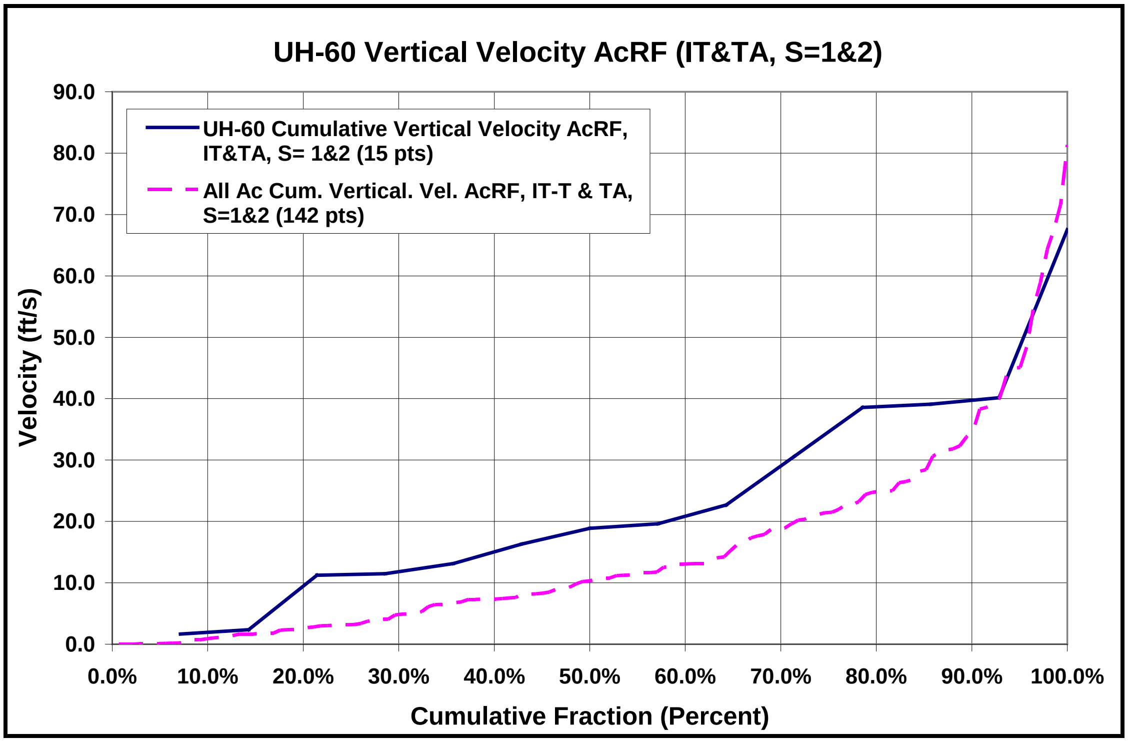

Figure A-78 – UH-60 Vertical Velocity AcRF (IT&TA, S=1&2)

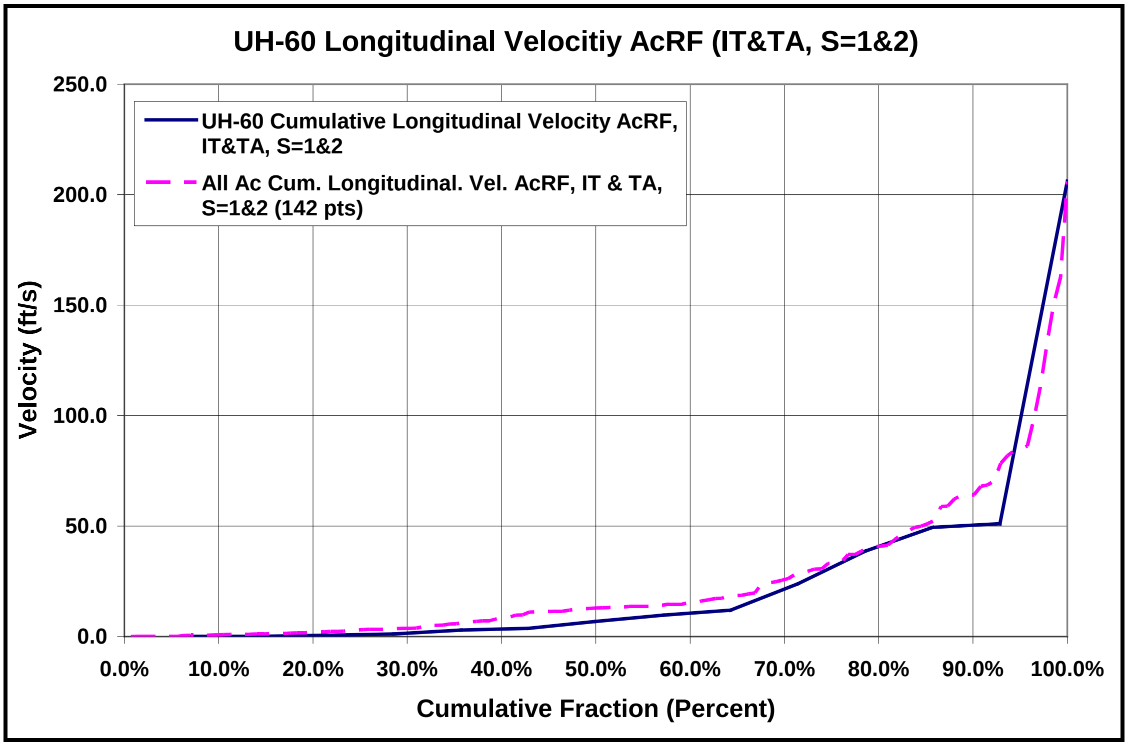

Figure A-79 – UH-60 Longitudinal Velocity AcRF (IT&TA, S=1&2)

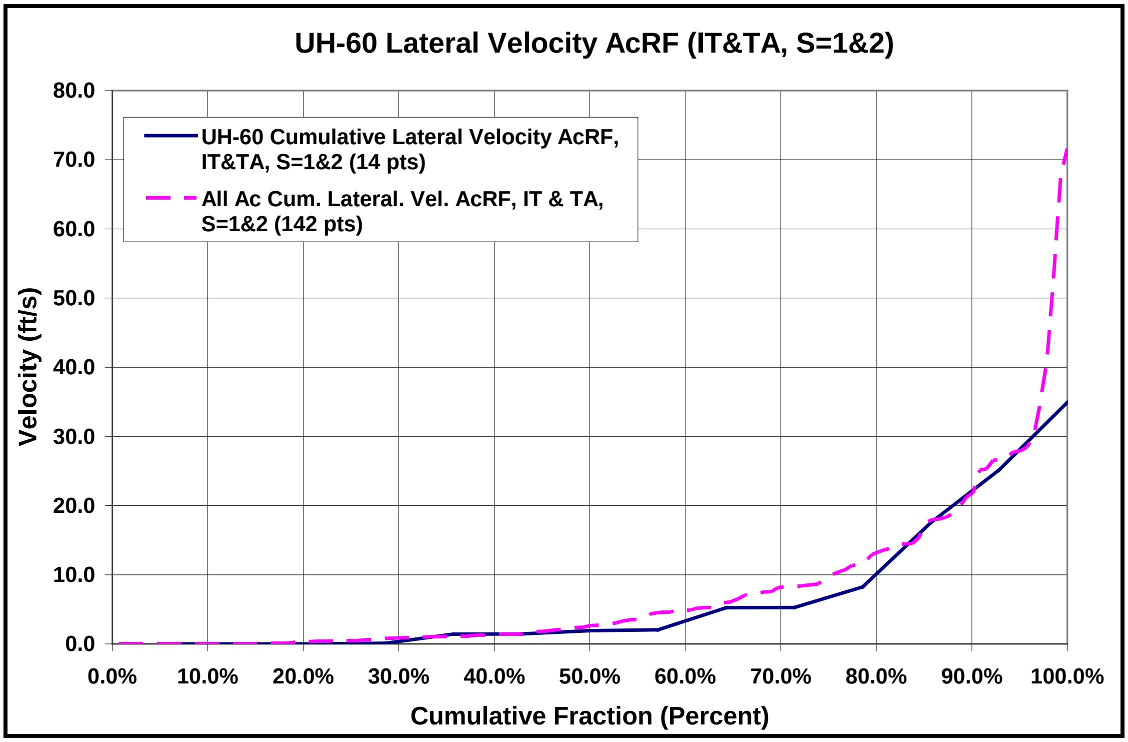

Figure A-80 – UH-60 Lateral Velocity AcRF (IT&TA, S=1&2)

Appendix B – Tables of Crash Velocity Medians and Means

Comparison of Velocity Populations for Terrain and Post-obstacle Crashes

Comparison of Velocity Populations for Terrain and Post-obstacle Crashes

The following tables compare the velocity populations of individual aircraft types and the population for all of the rotorcraft combined. The populations include all survivable and partially survivable crashes (S=1&2). The crashes directly into terrain (T) are compared to the crashes that follow a collision with an obstacle above ground level (IT&TA). The medians were tested for statistical significance using the Mann-Whitley Test. The value of the statistic "p" must be less than 0.05 for there to be 95 percent confidence that the medians of the two populations actually differ. The means were tested using the Two-Sample T Test. The value of the p must be less than 0.05 for there to be 95 percent confidence that the means actually differ.

The tables below present the median and mean values for each of the five velocities: vertical speed ERF, ground speed ERF, vertical velocity AcRF, longitudinal velocity AcRF, and lateral velocity AcRF. The data are organized with the five velocities for each aircraft in a single table. The p values for the two statistical tests are also listed in each table.

Most of these populations did not differ sufficiently to be statistically significant. The populations showing statistically significant differences for one parameter are: the lateral velocity means for the AH-64 and OH-58AC, the lateral velocity medians for the OH-58D, the vertical velocity means for the OH-58AC, and the ground speed for the OH-58D. The vertical speed for the UH-1 differed with statistical significance for both parameters. The values for the medians and the means are provided in the tables. In many cases, the calculated means or medians differ by an amount that has practical importance. However, the scatter in the data were such that the significance test failed.

Table B-1 – Median and Mean Values, AH-1

Velocity	Median T Crashes	Median IT&TA Crashes	p Value M-W Test	Mean T Crashes	Mean IT&TA Crashes	p Value TST Test
Vert. Speed	8.00	10.00	0.8437	12.1	13.9	0.579
Ground Speed	13.50	13.50	0.1894	29.7	23.1	0.430
Vert. Velocity	-9.31	-7.33	0.1200	-10.6	-6.1	0.245
Long. Velocity	13.03	13.59	0.5656	26.2	21.3	0.544
Lat. Velocity	0.00	-1.7	0.1283	-3.31	-1.0	0.532

Table B-2 – Median and Mean Values, AH-64

Velocity	Median T Crashes	Median IT&TA Crashes	p value M-W Test	Mean T Crashes	Mean IT&TA Crashes	p value TST Test
Vert. Speed	11.5	8.0	0.9689	17.8	14.4	0.517
Ground Speed	16.90	16.90	0.5330	42.1	30.5	0424
Vert. Velocity	-14.81	-16.67	0.8992	-16.6	-9.2	0.366
Long. Velocity	17.93	4.45	0.2504	39.2	20.4	0.166
Lat. Velocity	0.00	-0.09	0.0502	2.85	-9.7	0.029

Table B-3 – Median and Mean Values, CH-47

Velocity	Median T Crashes	Median IT&TA Crashes	p value M-W Test	Mean T Crashes	Mean IT&TA Crashes	p value TST Test
Vert. Speed	8.0	6.50	0.7905	12.8	6.5	0.128
Ground Speed	13.5	8.5	0.5952	32.8	8.5	0.133
Vert. Velocity	-9.51	-5.63	0.6420	-11.2	-5.63	0.371
Long. Velocity	7.53	7.93	0.5500	29.6	7.9	0.196
Lat. Velocity	0.581	-1.056	0.1439	1.84	-1.06	0.158

Table B-4 –Median and Mean Values, OH-6

Velocity	Median T Crashes	Median IT&TA Crashes [1]	p value M-W Test	Mean T Crashes	Mean IT&TA Crashes [1]	p value TST Test
Vert. Speed	4.5	-		8.25	-	
Ground Speed	13.5	-		18.25	-	
Vert. Velocity	-6.04	-		-8.15	-	
Long. Velocity	12.97	-		15.81	-	
Lat. Velocity	1.56	-		0.53	-	

[1] One usable crash

Table B-5 – Median and Mean Values, OH-58AC

Velocity	Median T Crashes	Median IT&TA Crashes	p value M-W Test	Mean T Crashes	Mean IT&TA Crashes	p value TST Test
Vert. Speed	8.0	8.0	0.2594	9.84	15.5	0.094
Ground Speed	13.5	8.40	0.3410	22.9	15.8	0.206
Vert. Velocity	-7.494	-0.052	0.0044	-9.7	-3.8	0.065
Long. Velocity	9.26	8.46	0.5902	21.2	15.8	0.387
Lat. Velocity	0.000	0.000	0.1499	-0.86	2.98	0.041

Table B-6 –Median and Mean Values, OH-58D

Velocity	Median T Crashes	Median IT&TA Crashes	p value M-W Test	Mean T Crashes	Mean IT&TA Crashes	p value TST Test
Vert. Speed	8.00	10.00	0.3470	11.5	17.0	0.346
Ground Speed	16.90	0.10	0.0240	30.9	16.1	0.253
Vert. Velocity	-8.80	-57-.72	0.3470	-16.3	-10.2	0.436
Long. Velocity	11.04	3.59	0.1118	25.2	15.0	0.401
Lat. Velocity	0.00	0.79	0.0299	-1.93	2.2	0.394

Table B-7 – Median and Mean Values, UH-1

Velocity	Median T Crashes	Median IT&TA Crashes	p value M-W Test	Mean T Crashes	Mean IT&TA Crashes	p value TST Test
Vert. Speed	8.00	12.00	0.0405	10.4	15.0	0.043
Ground Speed	13.50	13.50	0.7687	27.6	33.3	0.410
Vert. Velocity	-7.66	-7.53	0.5631	-9.8	-4.1	0.128
Long. Velocity	13.19	13.84	0.5335	34.4	40.1	0.405
Lat. Velocity	0.000	0.000	0.9704	-0.66	-0.2	0.828

Table B-8 – Median and Mean Values, UH-60

Velocity	Median T Crashes	Median IT&TA Crashes	p value M-W Test	Mean T Crashes	Mean IT&TA Crashes	p value TST Test
Vert. Speed	12.0	19.0	0.3413	17.6	27.8	0.256
Ground Speed	8.40	5.90	0.6290	29.7	27.3	0.882
Vert. Velocity	-11.63	-16.01	0.8262	-16.5	-16.0	0.945
Long. Velocity	8.73	2.15	0.2188	27.3	20.4	0.696
Lat. Velocity	0.07	0.70	0.7809	2.0	5.1	0.419

Table B-9 – Median and Mean Values, All Aircraft

Velocity	Median T Crashes	Median IT&TA Crashes	p value M-W Test	Mean T Crashes	Mean IT&TA Crashes	p value TST Test
Vert. Speed	9.00	9.90	0.075	14.0	16.5	0.118
Ground Speed	13.50*	13.50*	0.044	28.3	25.4	0.429

*Verified these values are equal.

Appendix C – Velocity Scatter Plots

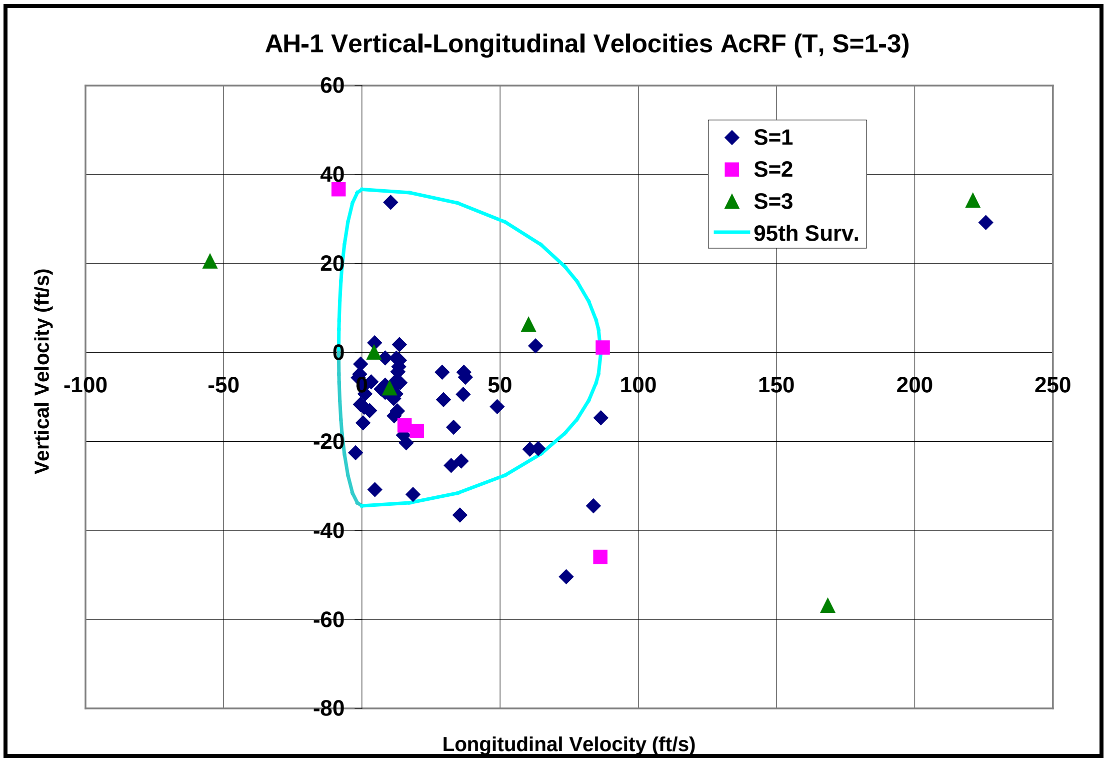

Figure C-1 – AH-1 Vertical-Longitudinal Velocities AcRF (T, S=1-3)

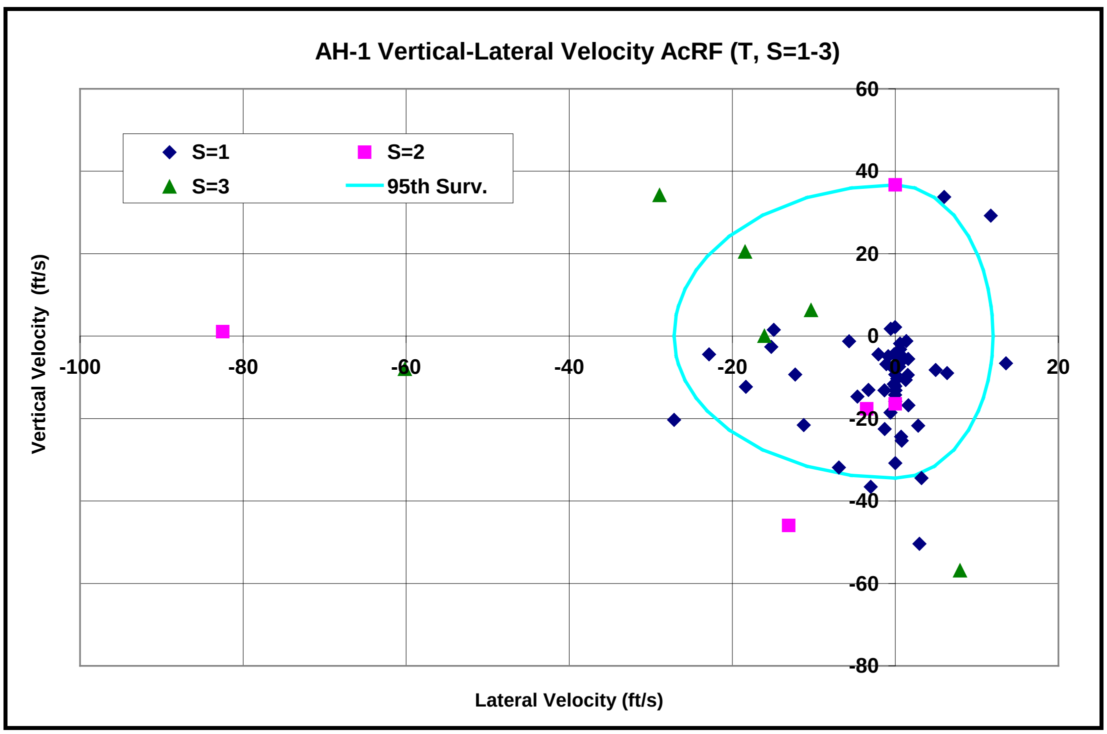

Figure C-2 – AH-1 Vertical-Lateral Velocity AcRF (T, S=1-3)

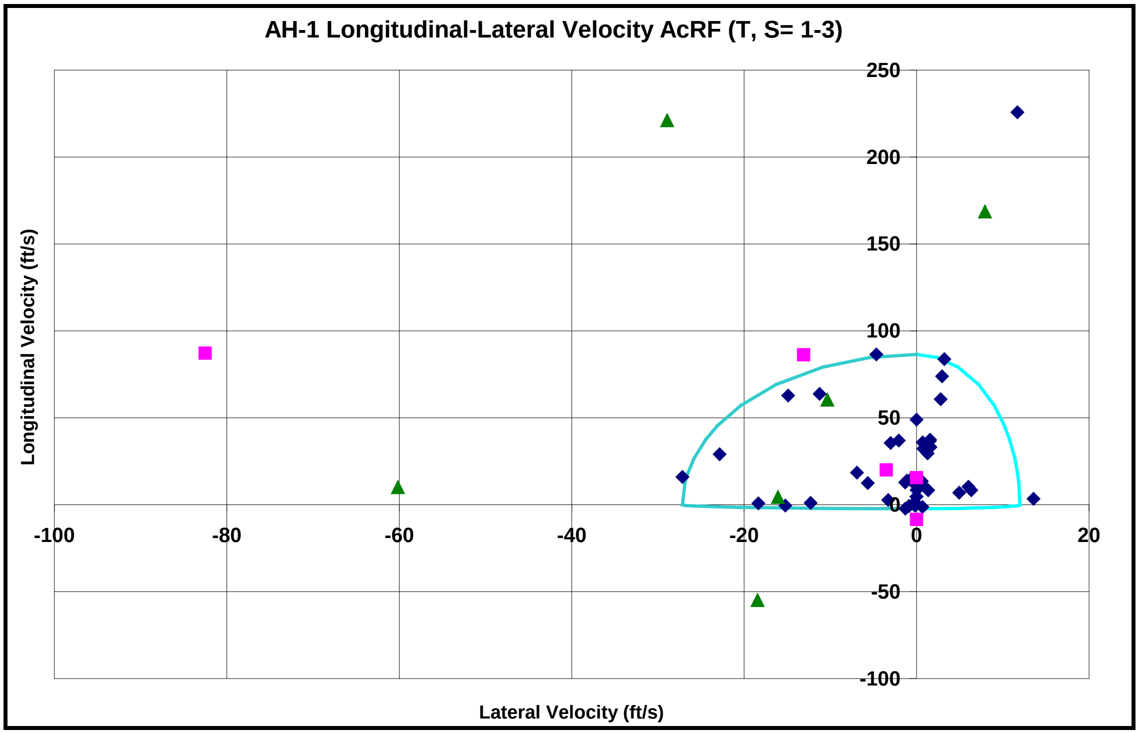

Figure C-3 – AH-1 Longitudinal-Lateral Velocity AcRF (T, S= 1-3)

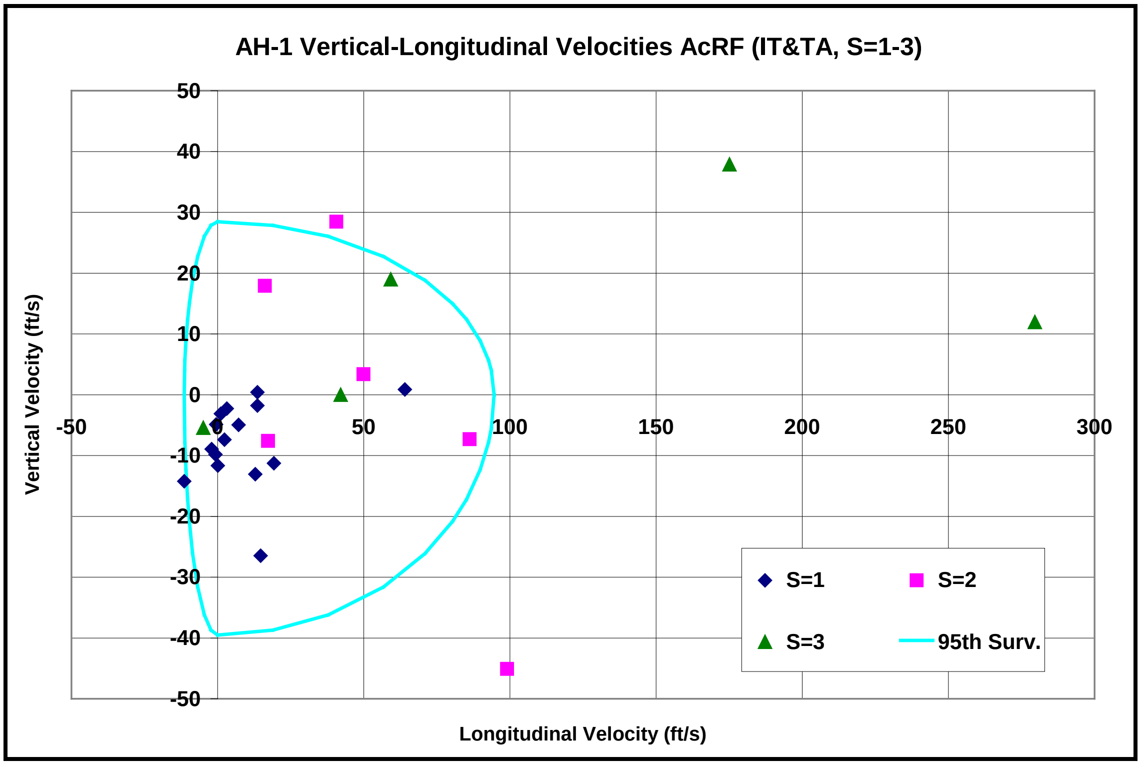

Figure C-4 – AH-1 Vertical-Longitudinal Velocities AcRF (IT&TA, S=1-3)

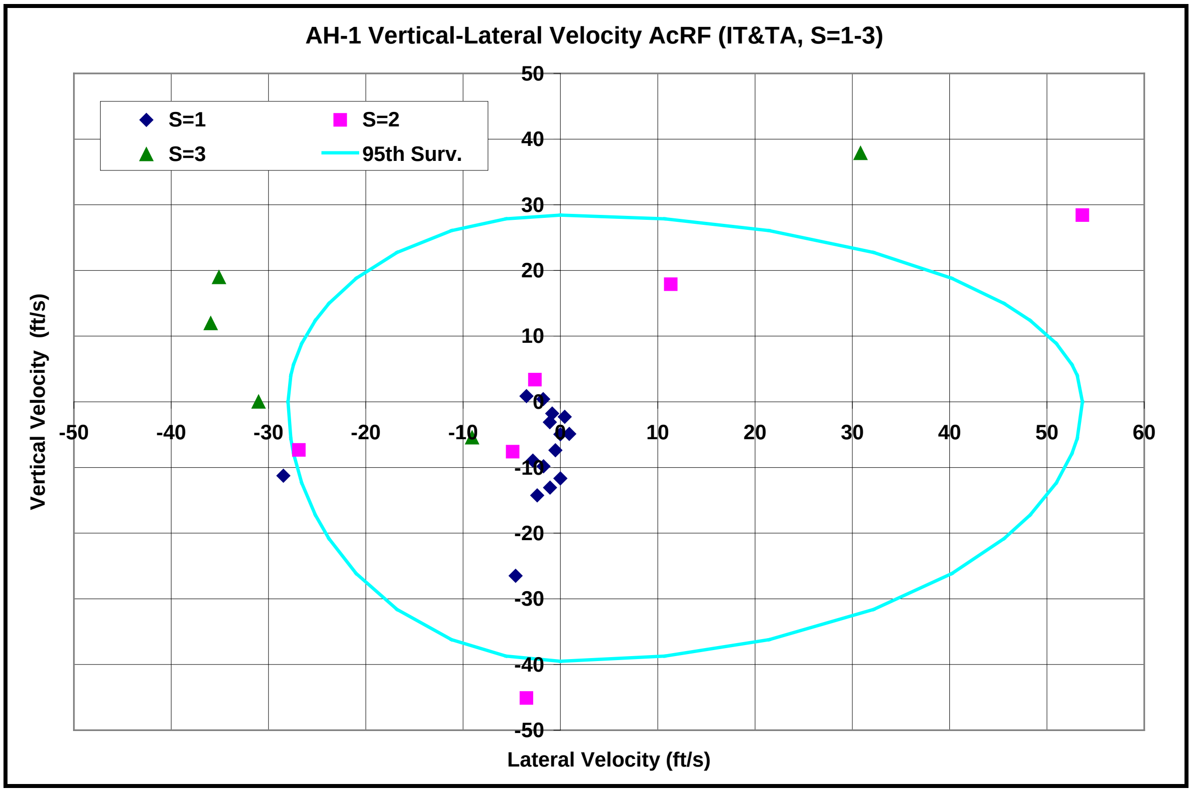

Figure C-5 – AH-1 Vertical-Lateral Velocity AcRF (IT&TA, S=1-3)

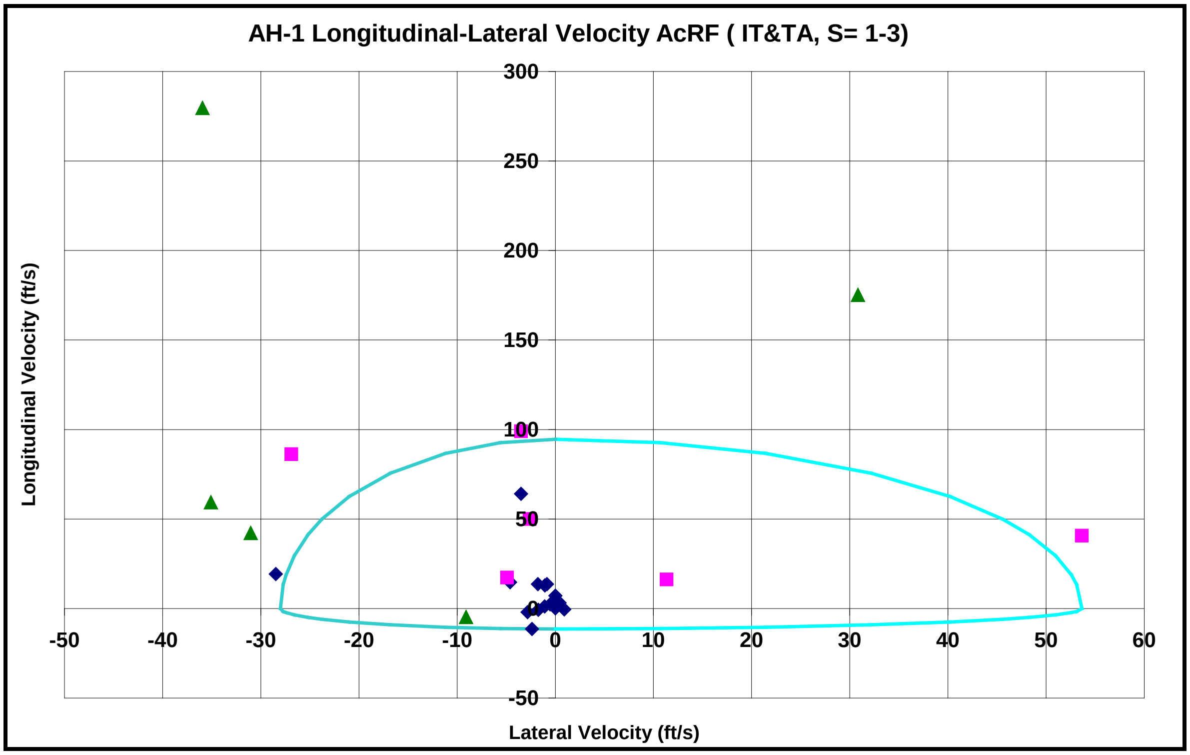

Figure C-6 – AH-1 Longitudinal-Lateral Velocity AcRF (IT&TA, S= 1-3)

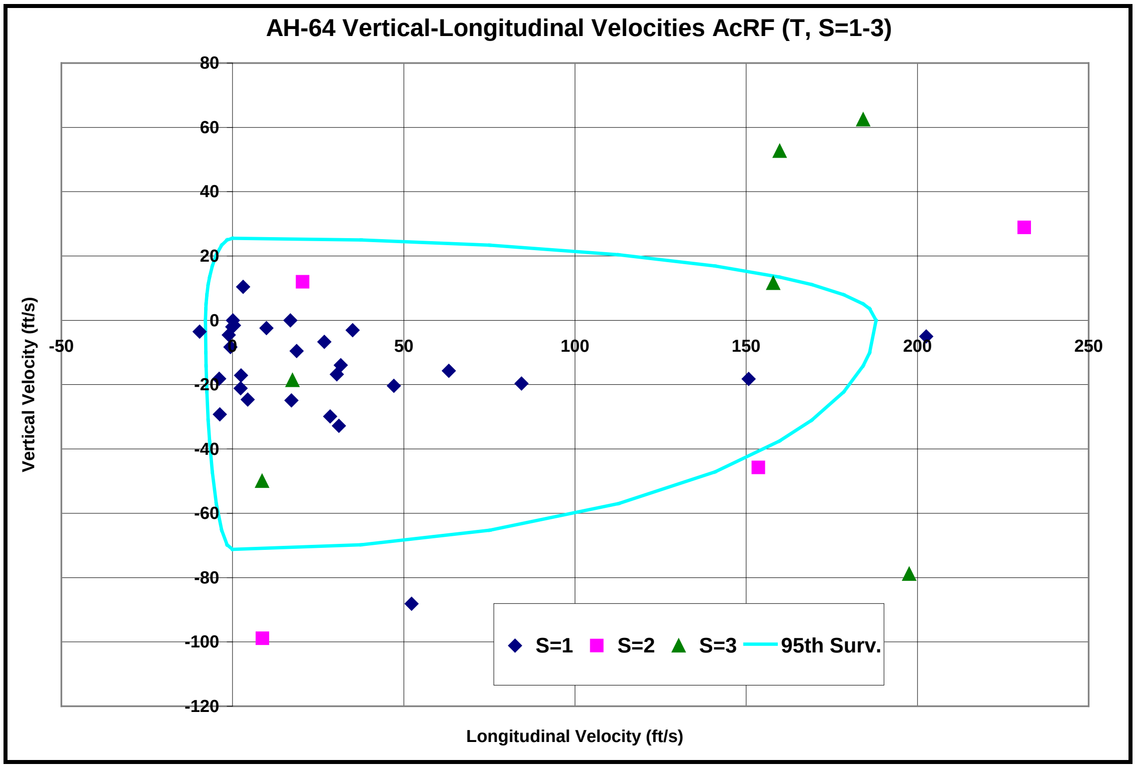

Figure C-7 – AH-64 Vertical-Longitudinal Velocities AcRF (T, S=1-3)

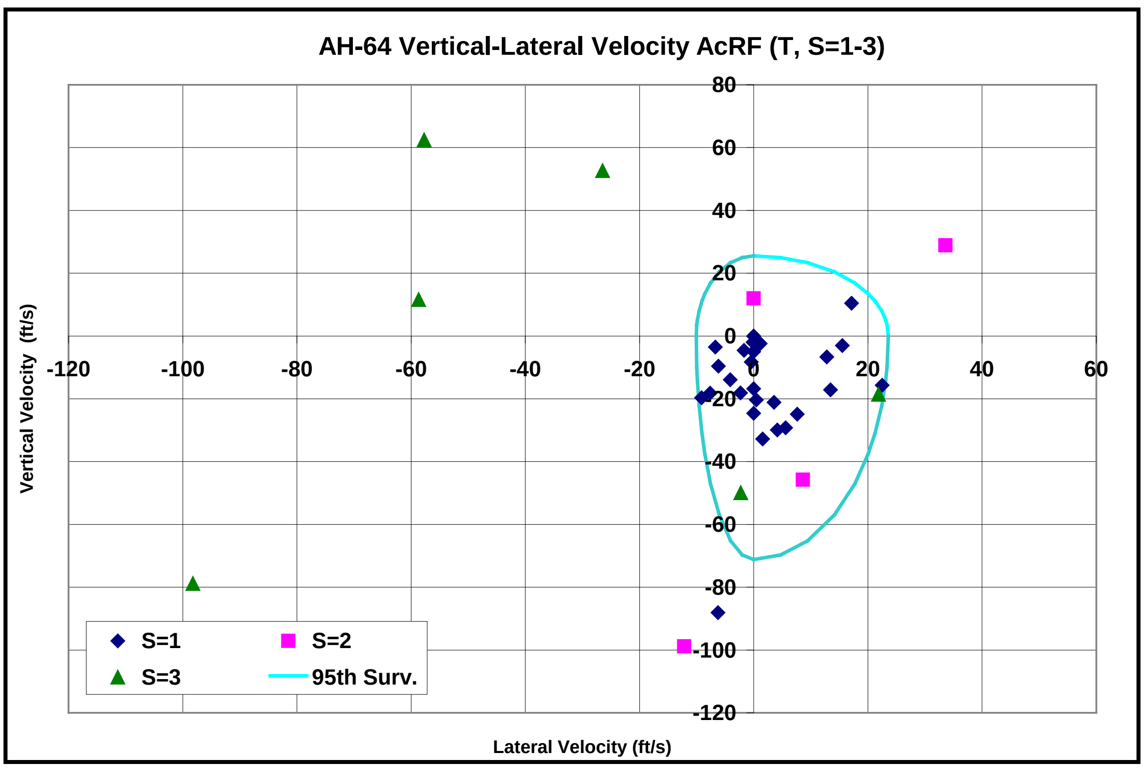

Figure C-8 – AH-64 Vertical-Lateral Velocity AcRF (T, S=1-3)

Distribution: Unlimited

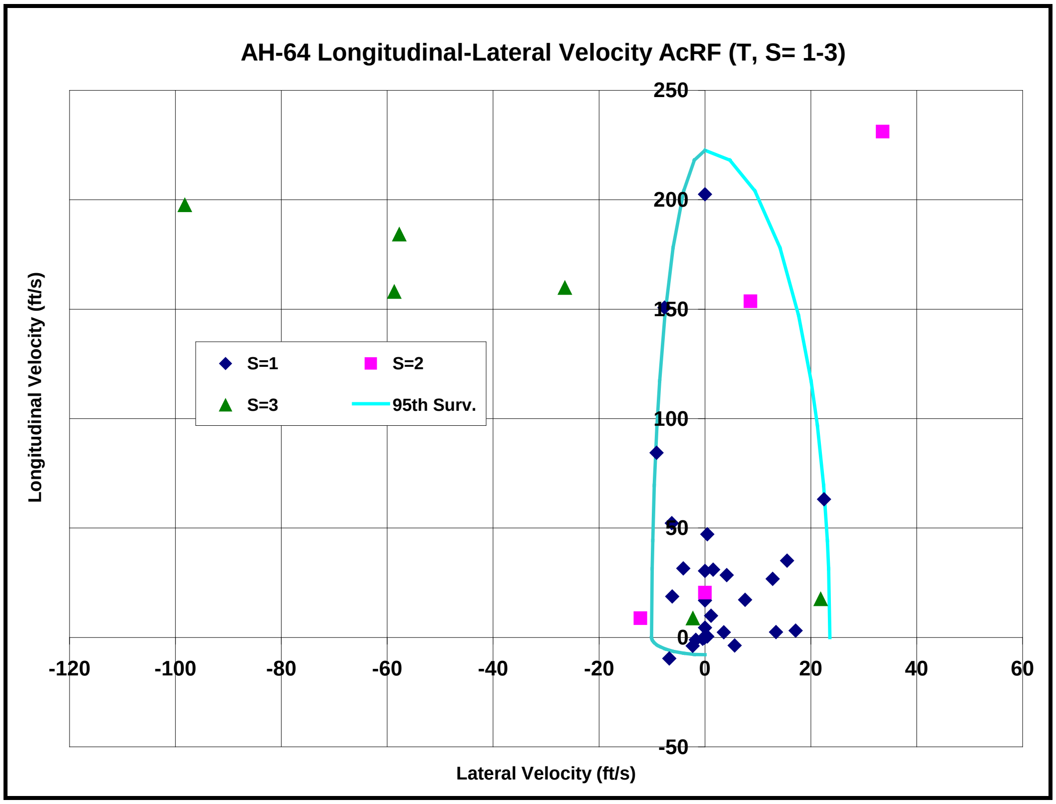

Figure C-9 – AH-64 Longitudinal-Lateral Velocity AcRF (T, S= 1-3)

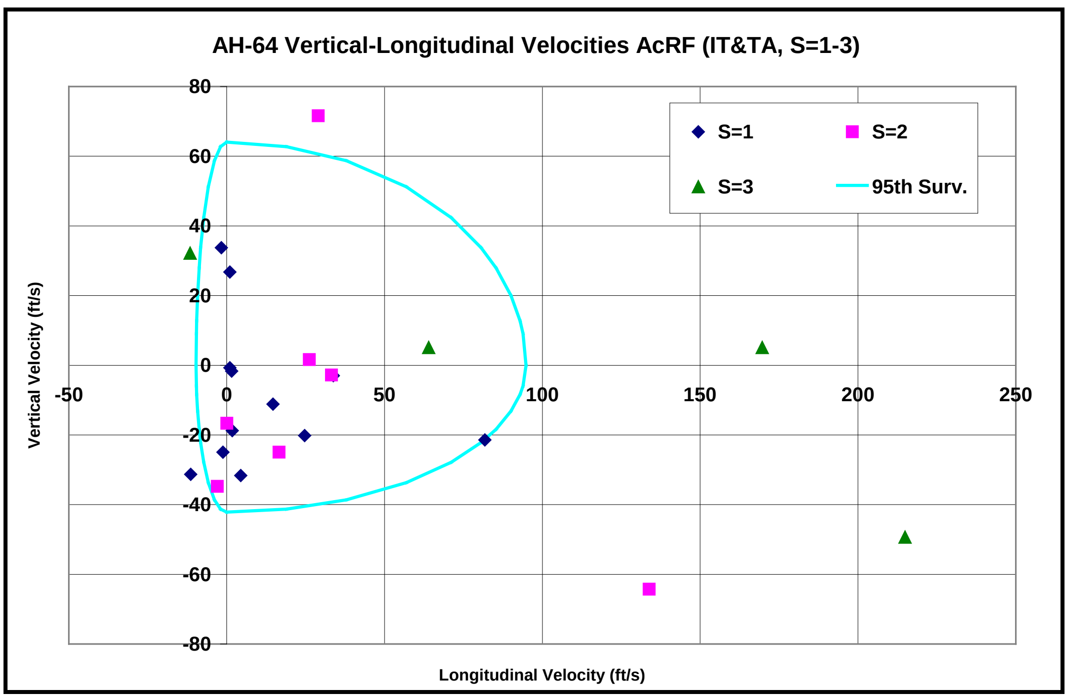

Figure C-10 – AH-64 Vertical-Longitudinal Velocities AcRF (IT&TA, S=1-3)

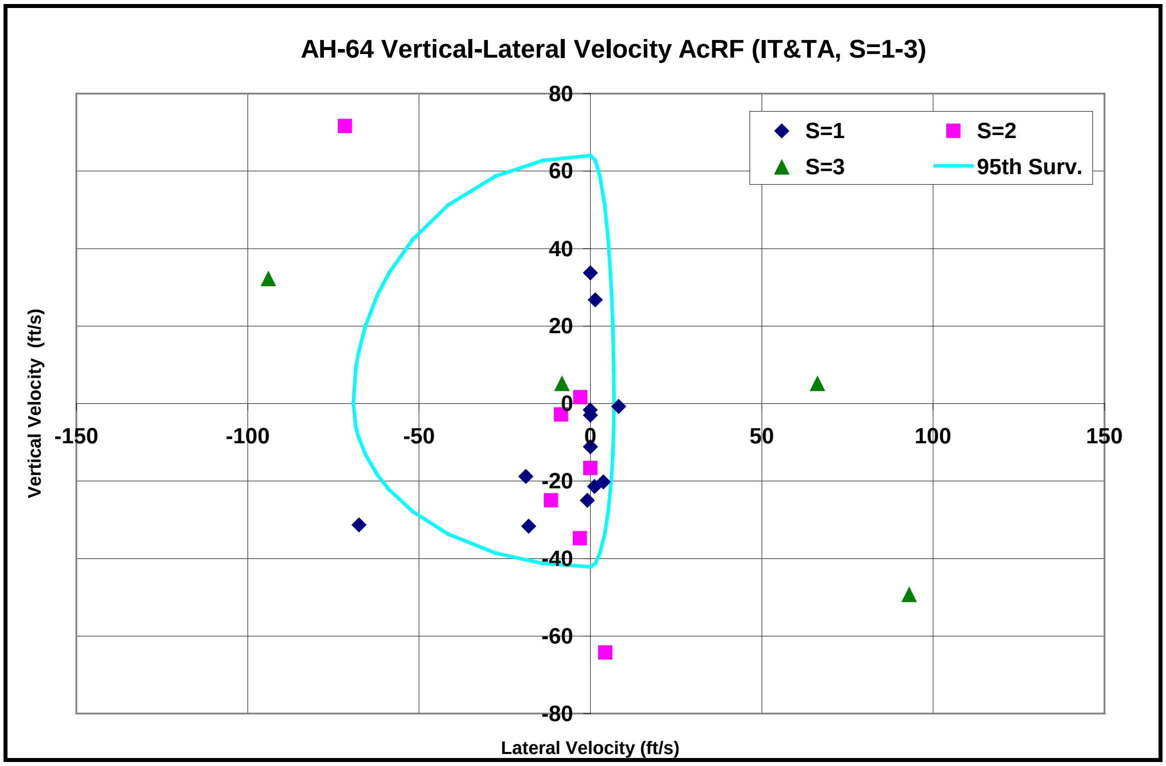

Figure C-11 – AH-64 Vertical-Lateral Velocity AcRF (IT&TA, S=1-3)

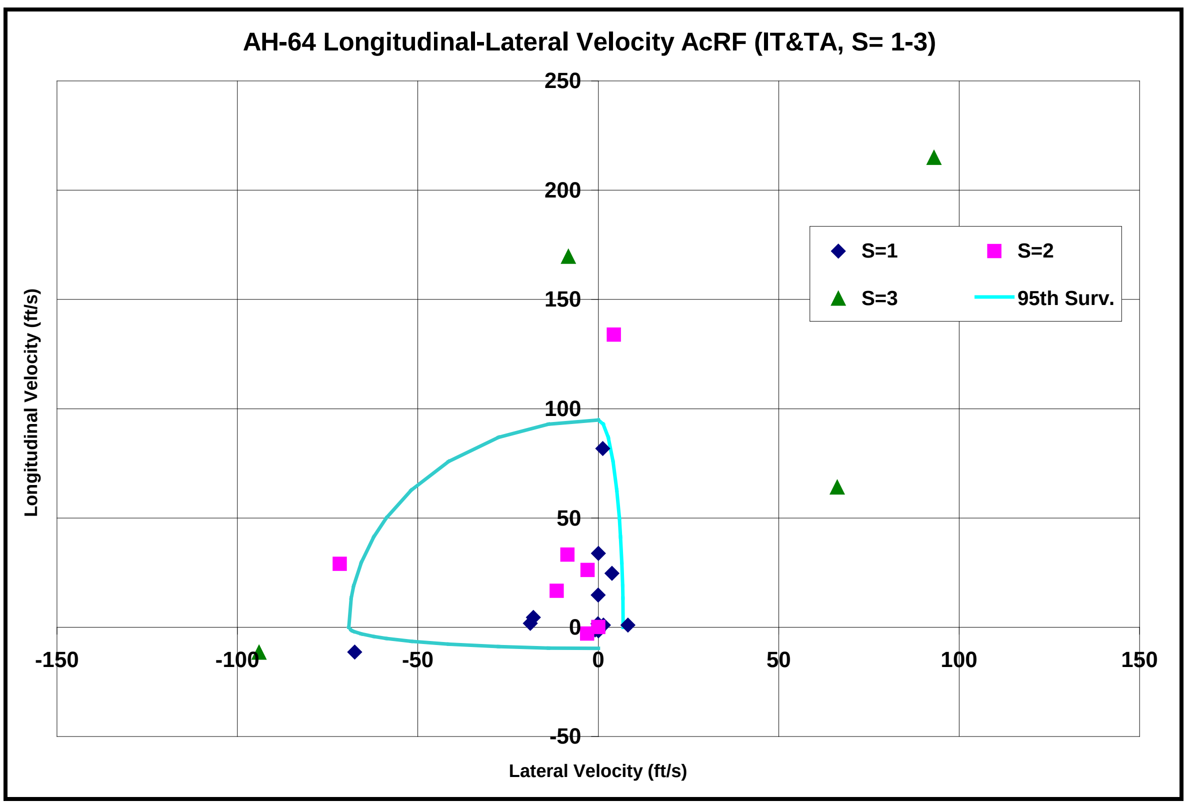

Figure C-12 – AH-64 Longitudinal-Lateral Velocity AcRF (IT&TA, S= 1-3)

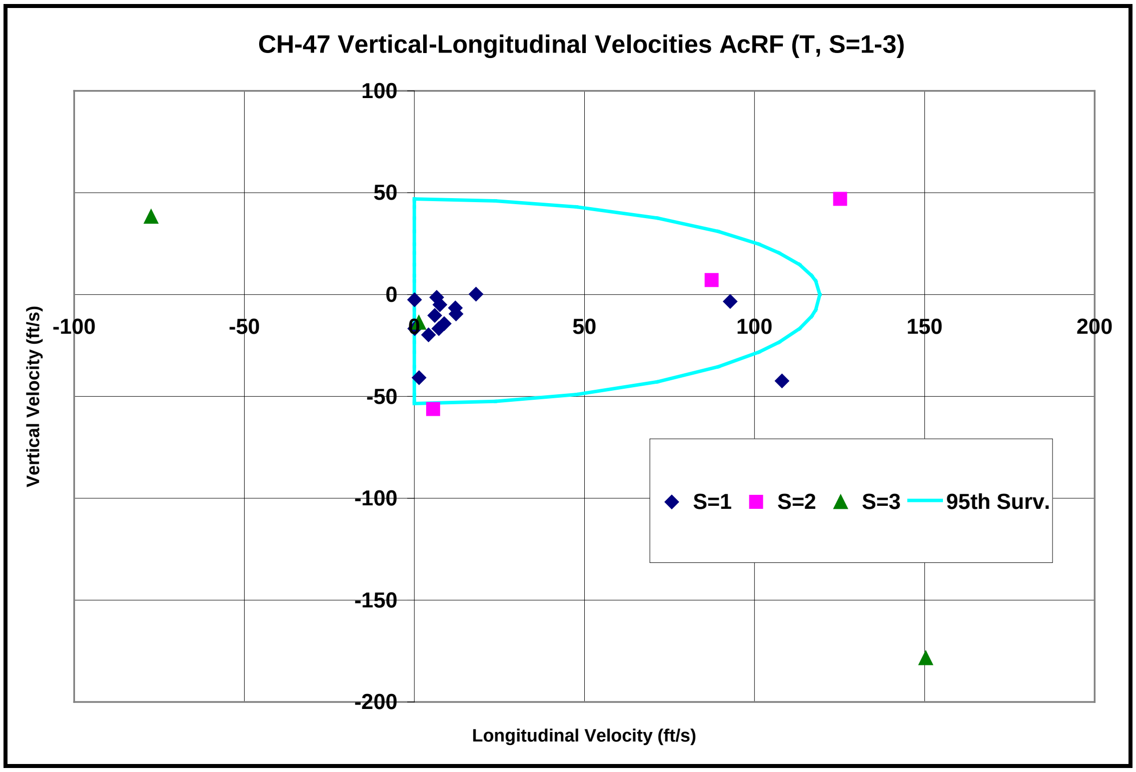

Figure C-13 – CH-47 Vertical-Longitudinal Velocities AcRF (T, S=1-3)

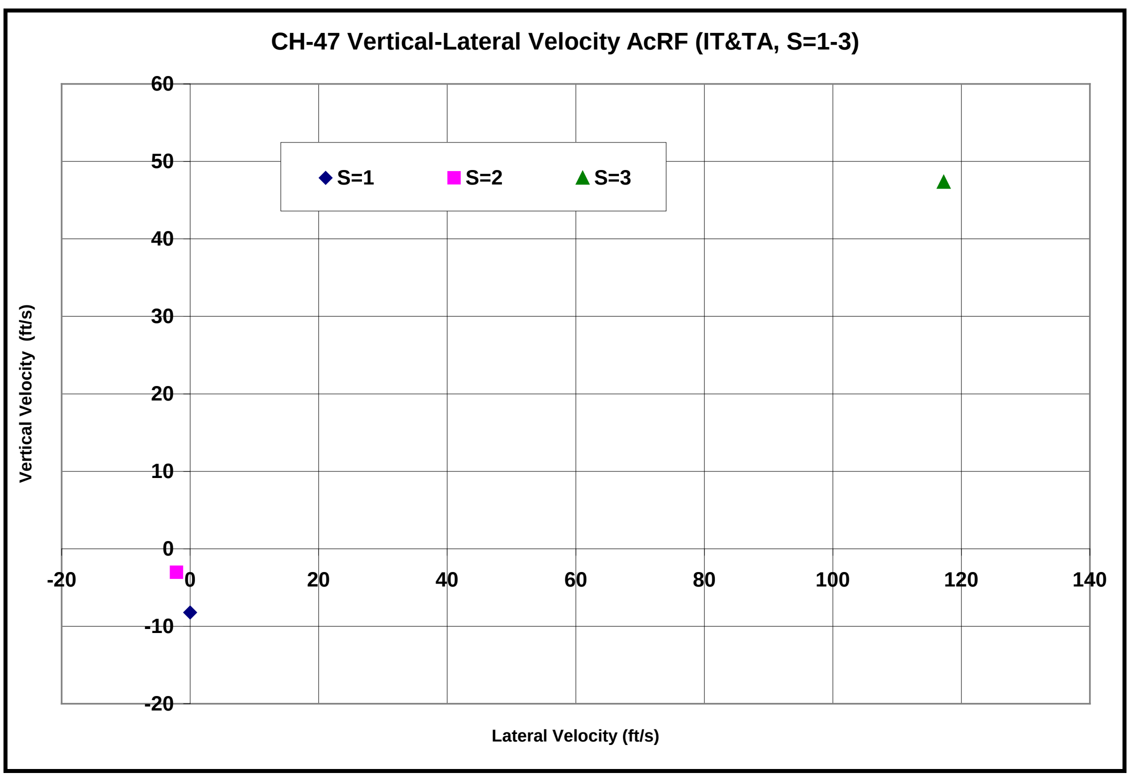

Figure C-14 – CH-47 Vertical-Lateral Velocity AcRF (T, S=1-3)

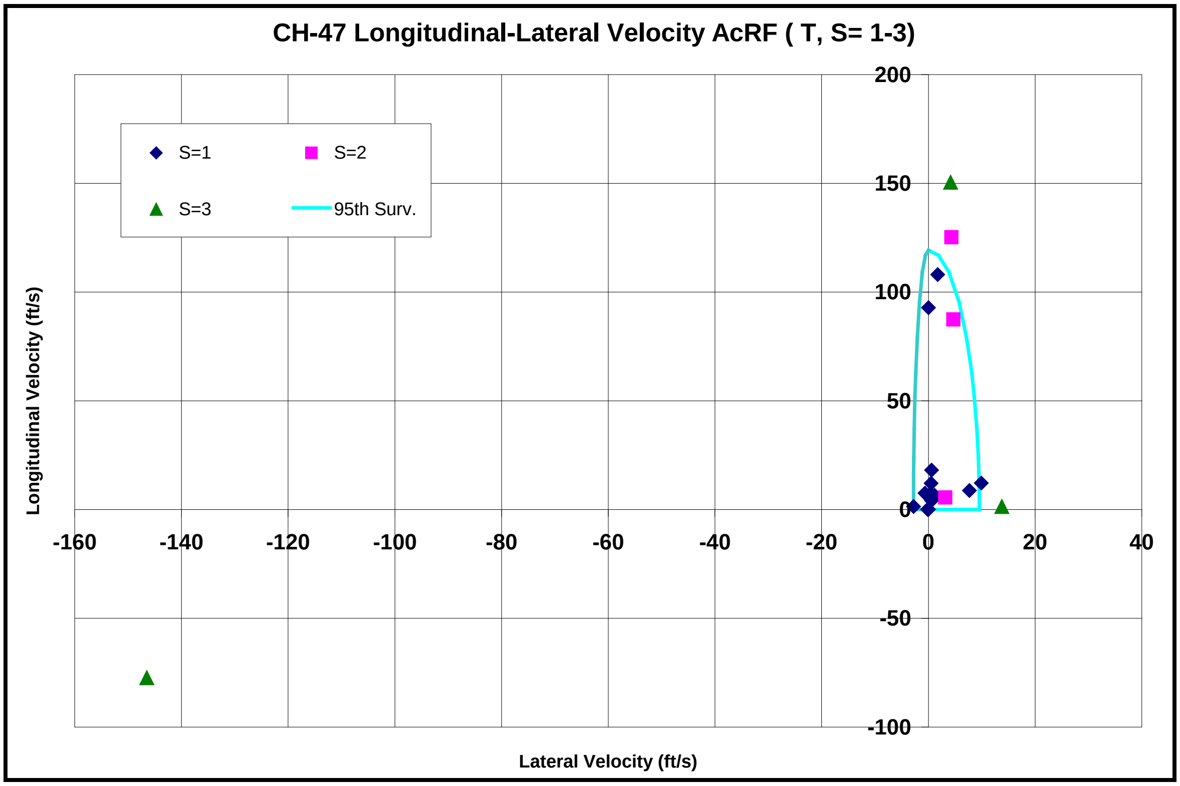

Figure C-15 – CH-47 Longitudinal-Lateral Velocity AcRF (T, S= 1-3)

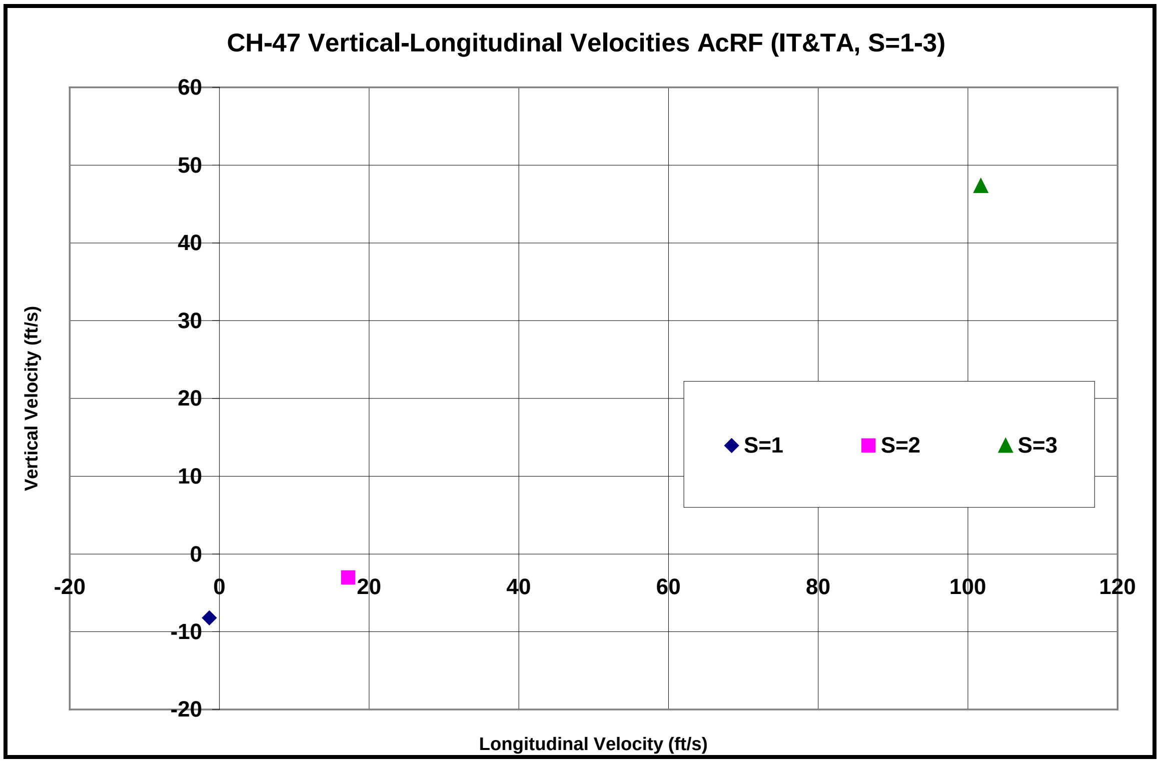

Figure C-16 – CH-47 Vertical-Longitudinal Velocities AcRF (IT&TA, S=1-3)

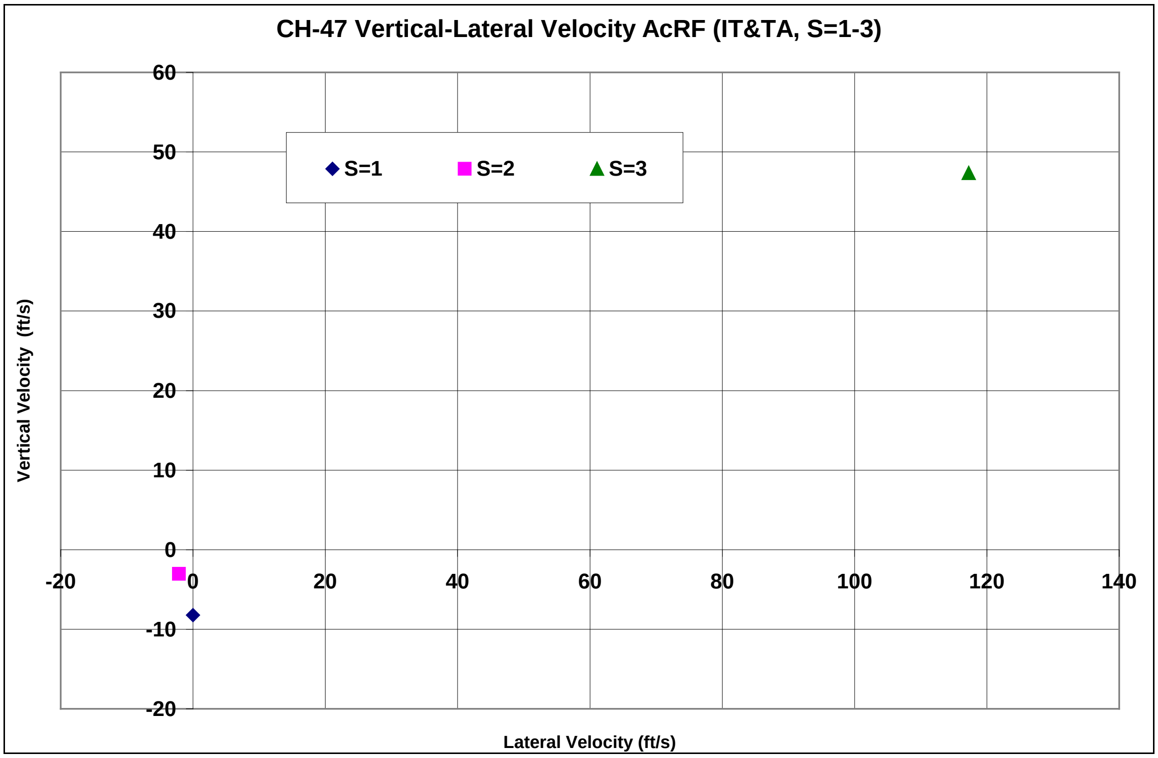

Figure C-17 – CH-47 Vertical-Lateral Velocity AcRF (IT&TA, S=1-3)

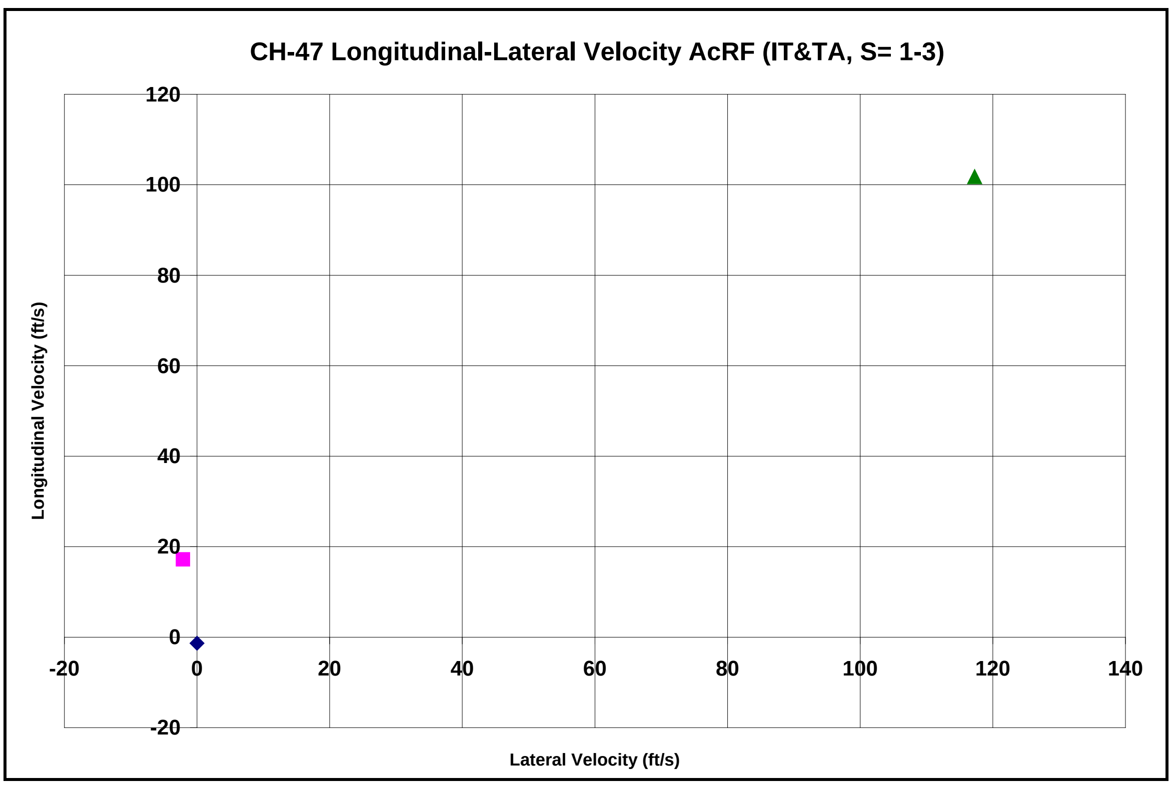

Figure C-18 – CH-47 Longitudinal-Lateral Velocity AcRF (IT&TA, S= 1-3)

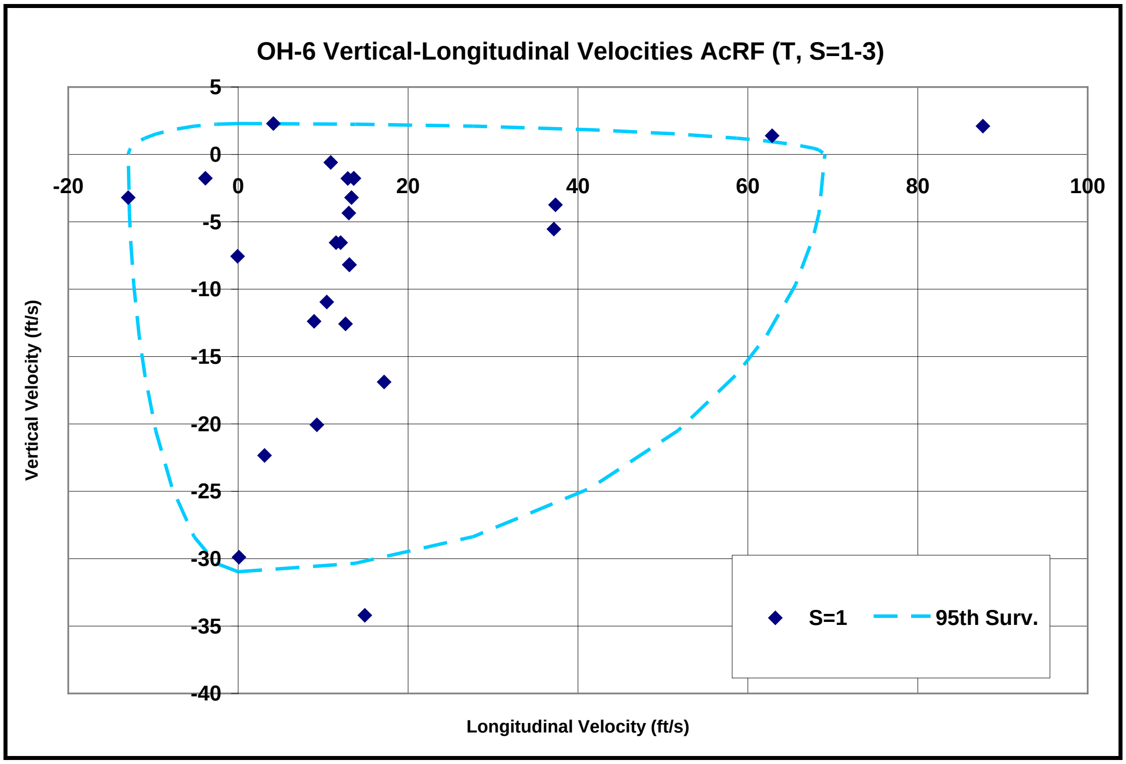

Figure C-19 – OH-6 Vertical-Longitudinal Velocities AcRF (T, S=1-3)

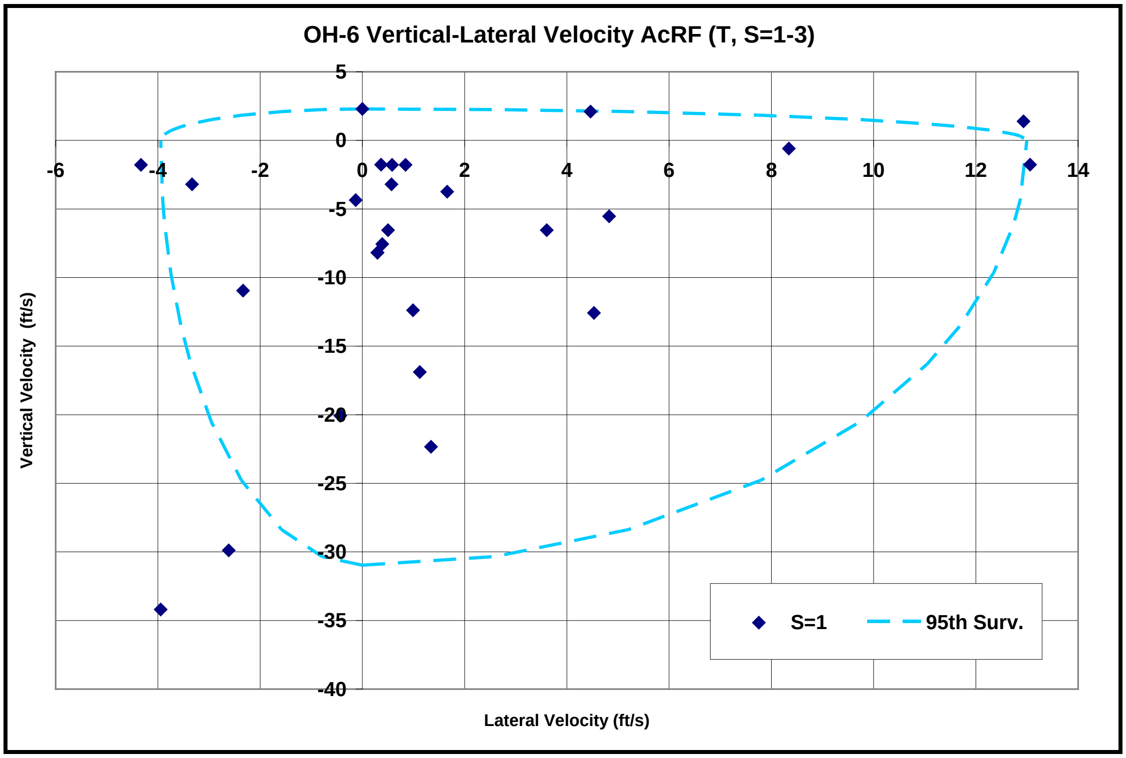

Figure C-20 – OH-6 Vertical-Lateral Velocity AcRF (T, S=1-3)

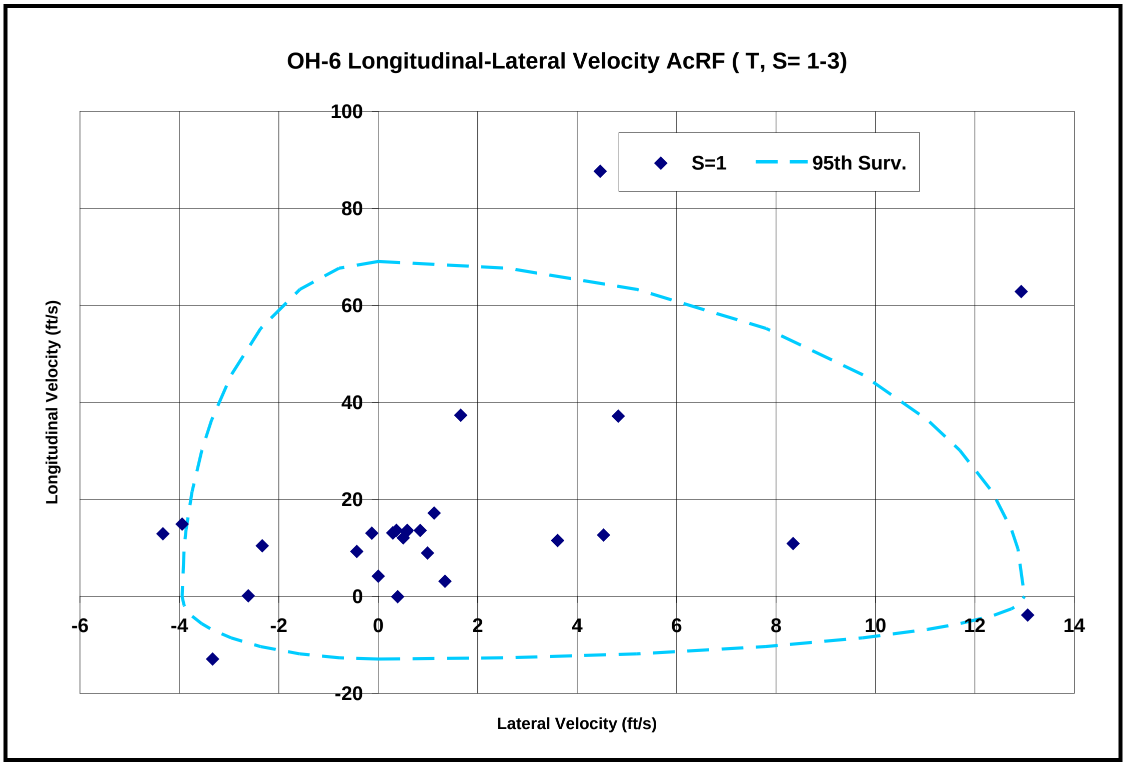

Figure C-21 – OH-6 Longitudinal-Lateral Velocity AcRF (T, S= 1-3)

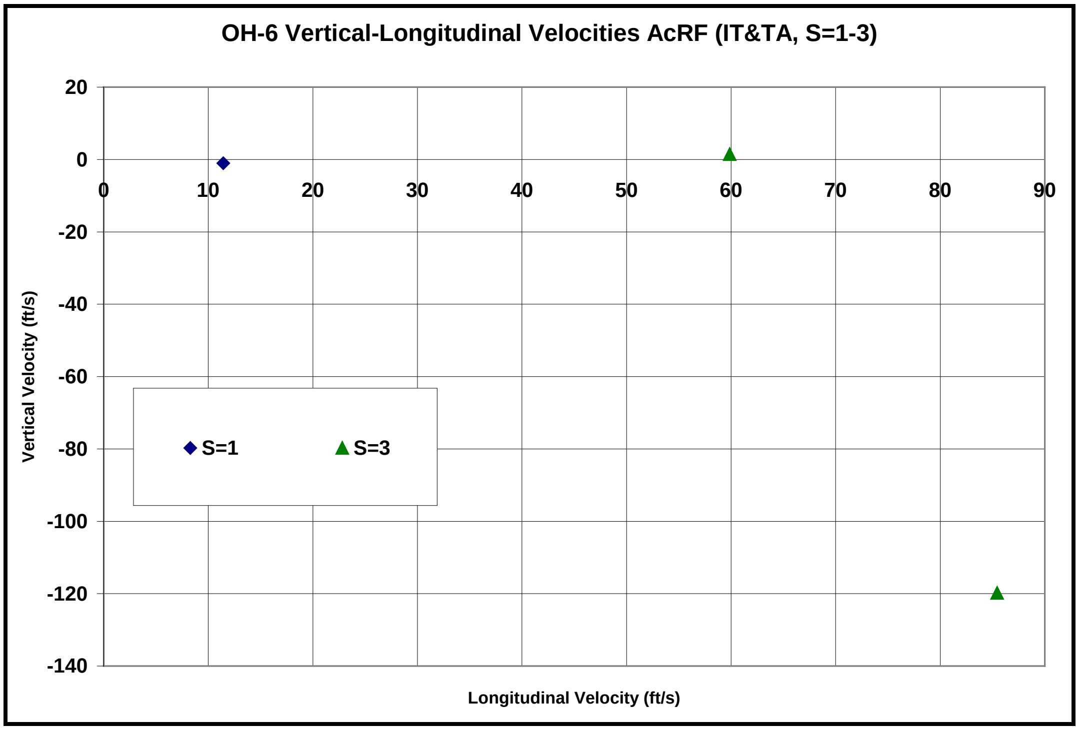

Figure C-22 – OH-6 Vertical-Longitudinal Velocities AcRF (IT&TA, S=1-3)

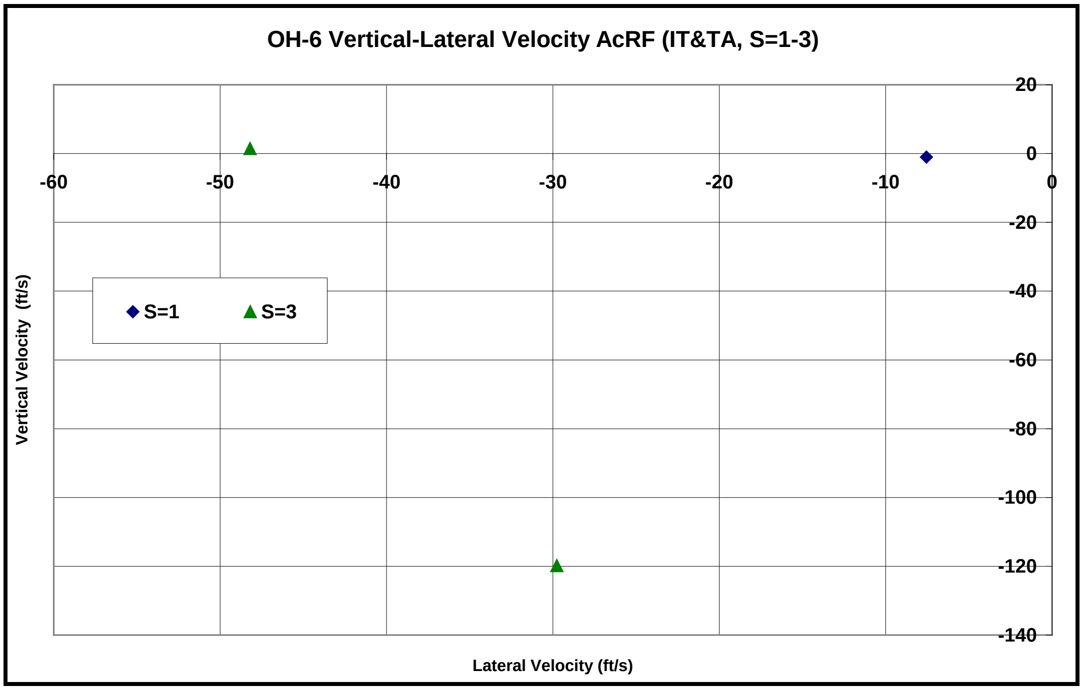

Figure C-23 – OH-6 Vertical-Lateral Velocity AcRF (IT&TA, S=1-3)

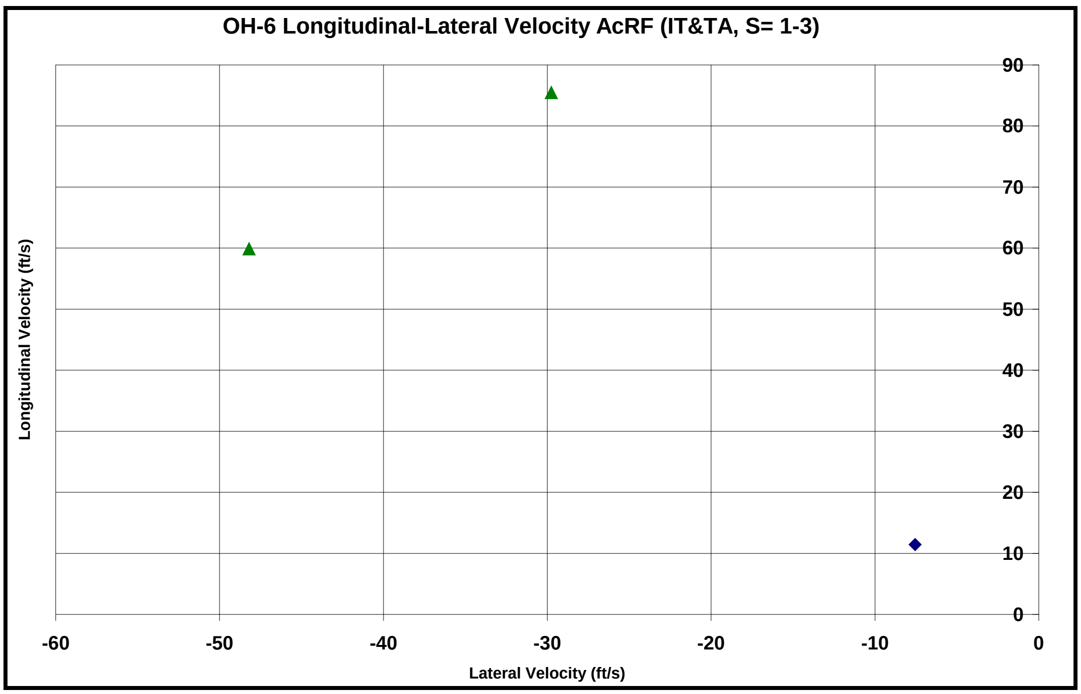

Figure C-24 – OH-6 Longitudinal-Lateral Velocity AcRF (IT&TA, S= 1-3)

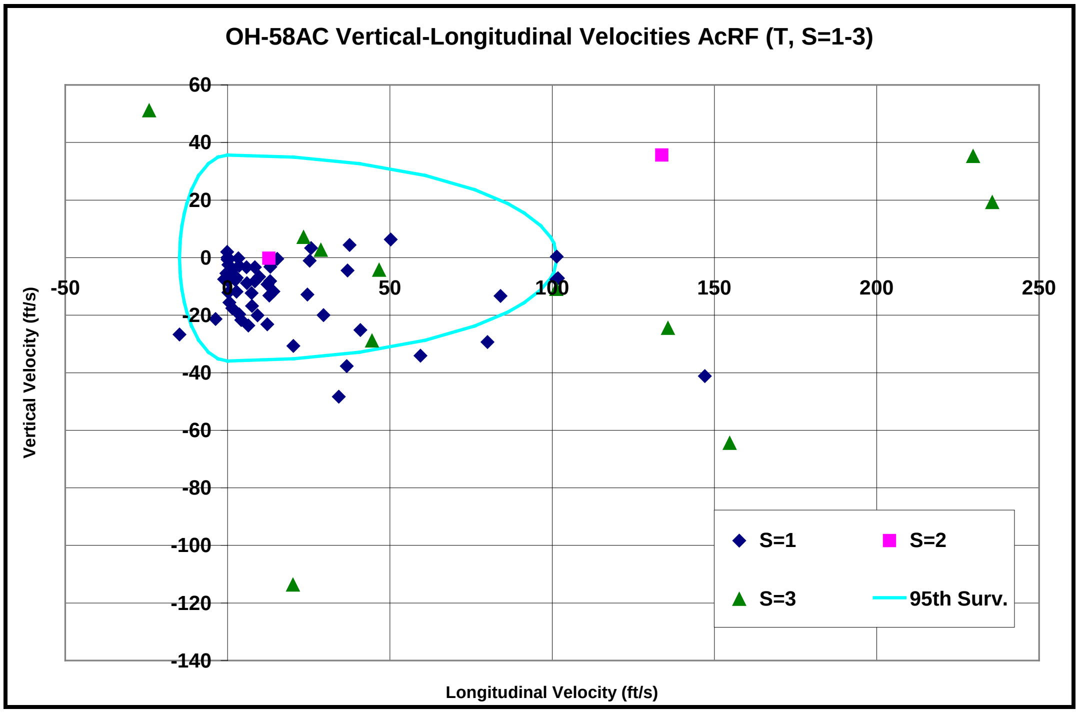

Figure C-25 – OH-58AC Vertical-Longitudinal Velocities AcRF (T, S=1-3)

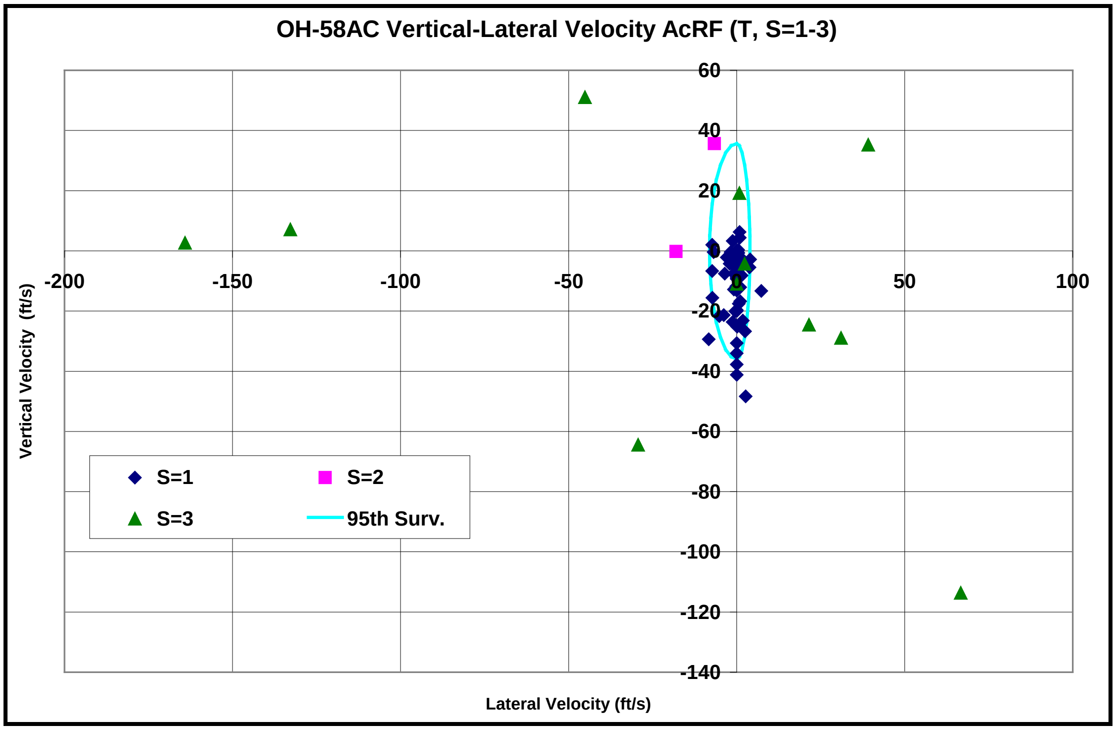

Figure C-26 – OH-58AC Vertical-Lateral Velocity AcRF (T, S=1-3)

Distribution: Unlimited

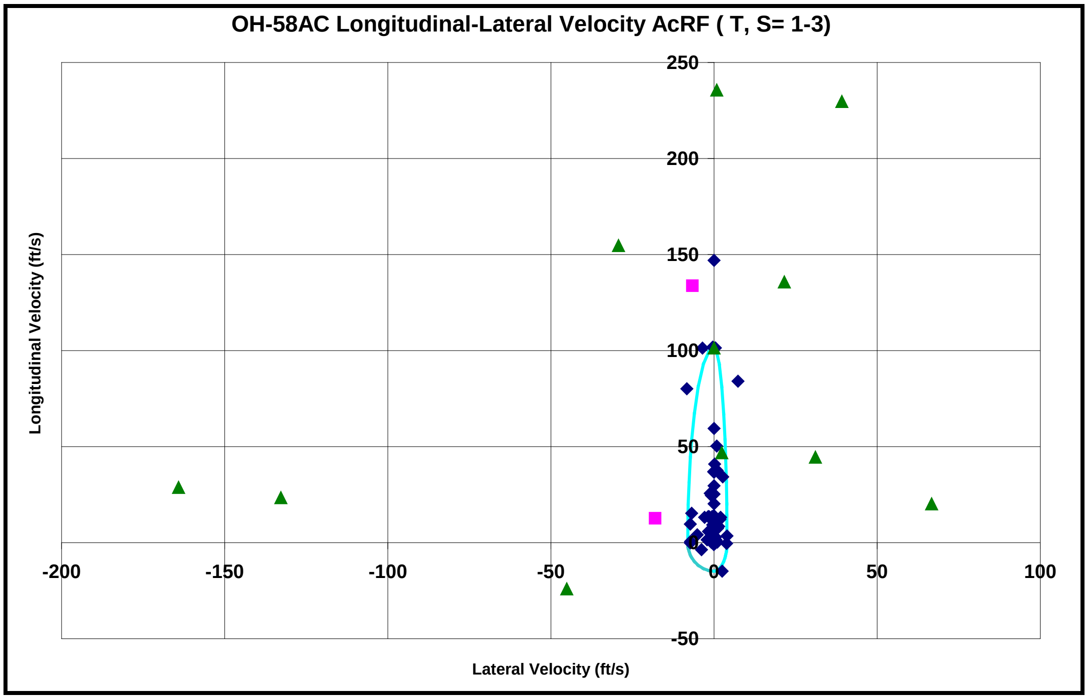

Figure C-27 – OH-58AC Longitudinal-Lateral Velocity AcRF (T, S= 1-3)

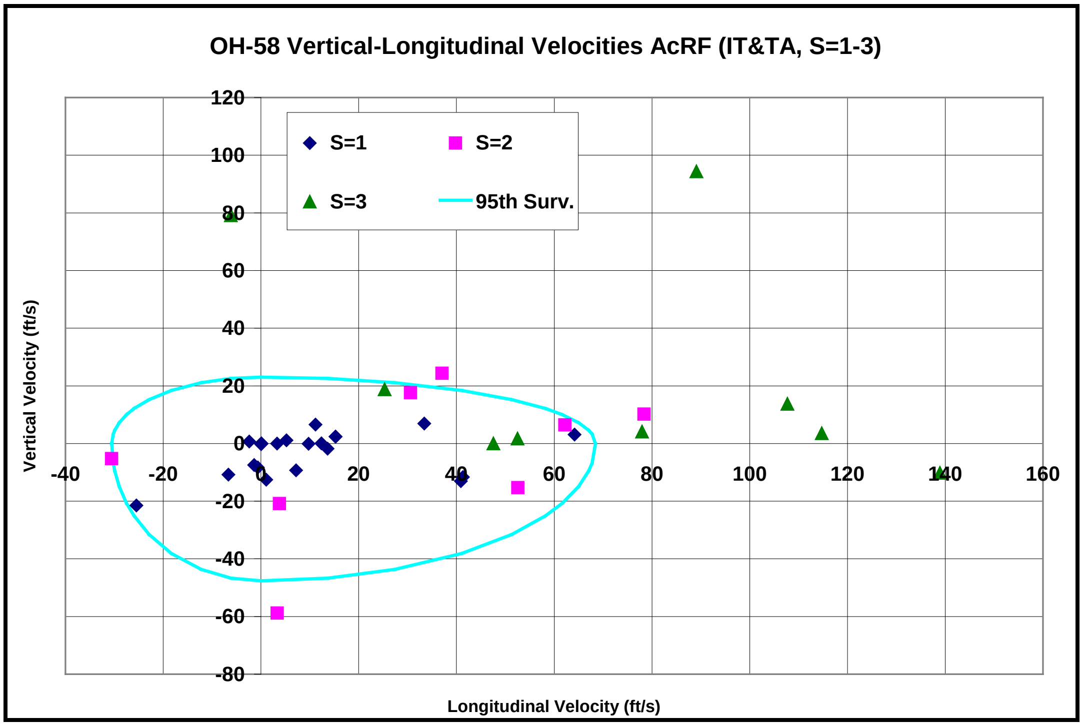

Figure C-28 – OH-58AC Vertical-Longitudinal Velocities AcRF (IT&TA, S=1-3)

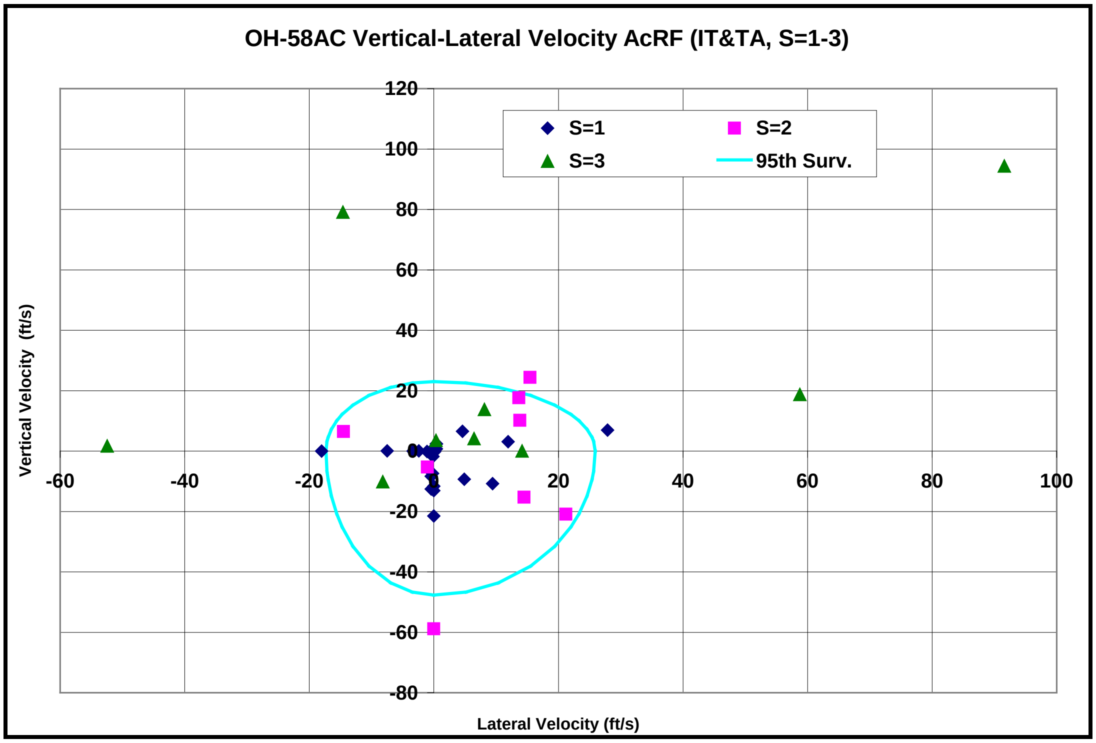

Figure C-29 – OH-58AC Vertical-Lateral Velocity AcRF (IT&TA, S=1-3)

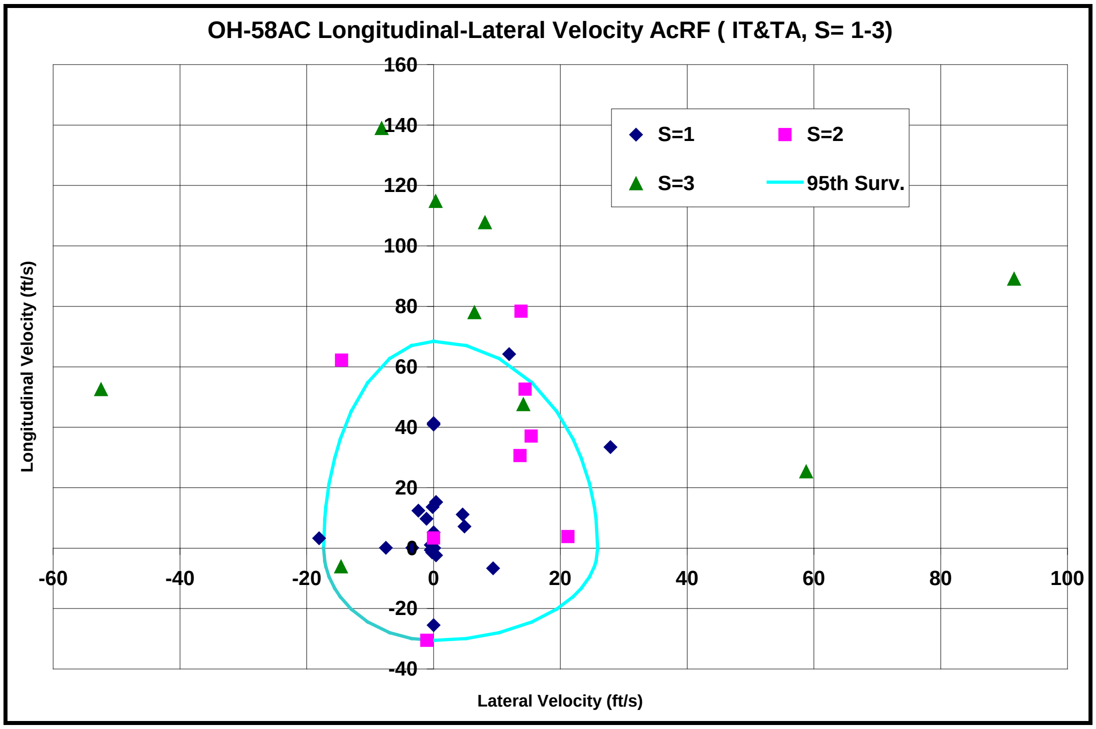

Figure C-30 – OH-58AC Longitudinal-Lateral Velocity AcRF (IT&TA, S= 1-3)

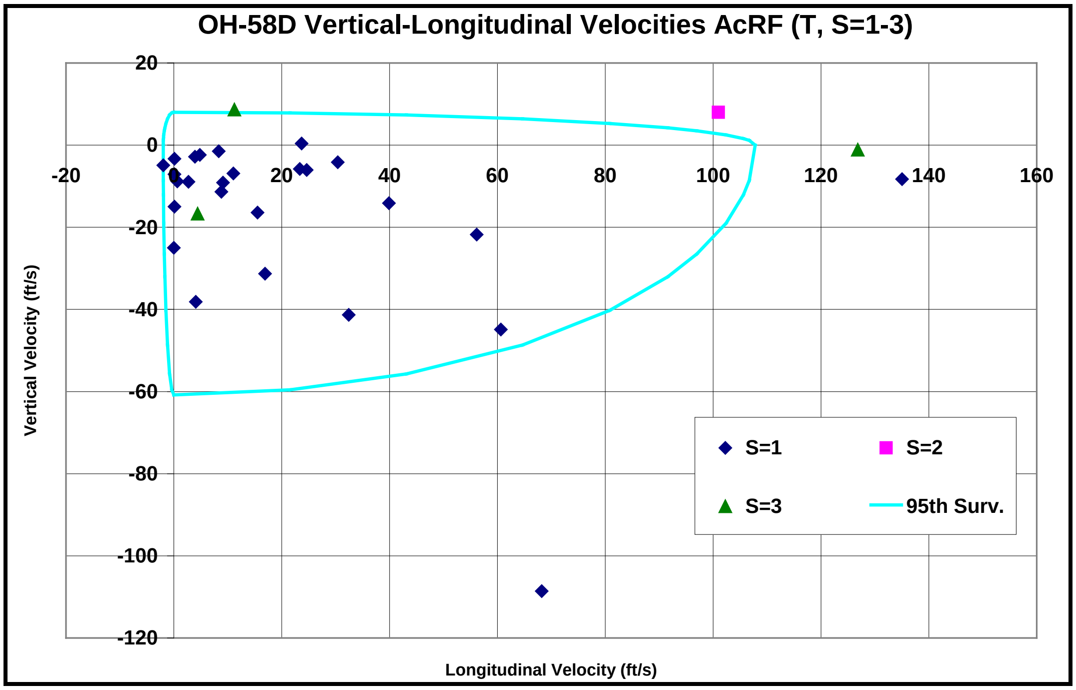

Figure C-31 – OH-58D Vertical-Longitudinal Velocities AcRF (T, S=1-3)

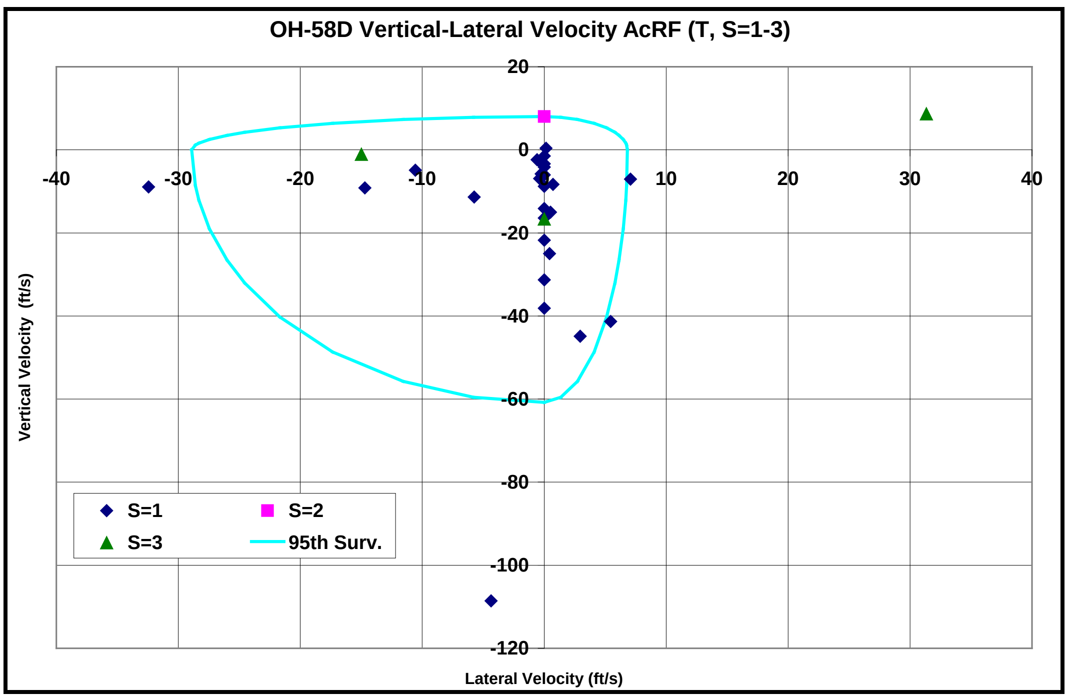

Figure C-32 – OH-58D Vertical-Lateral Velocity AcRF (T, S=1-3)

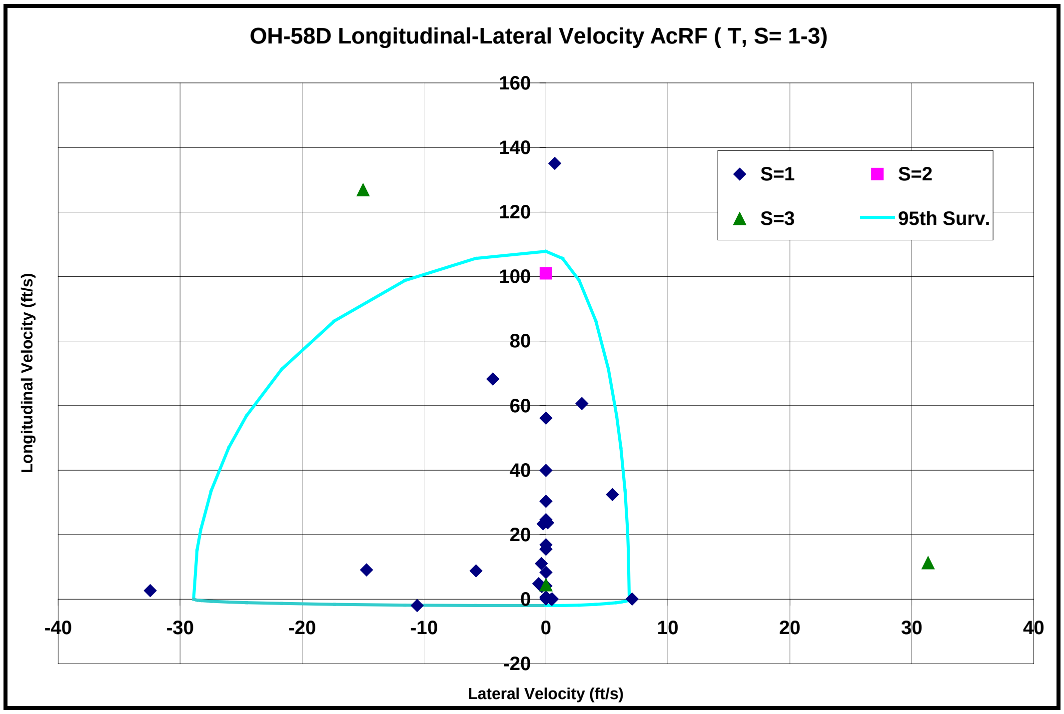

Figure C-33 – OH-58D Longitudinal-Lateral Velocity AcRF (T, S= 1-3)

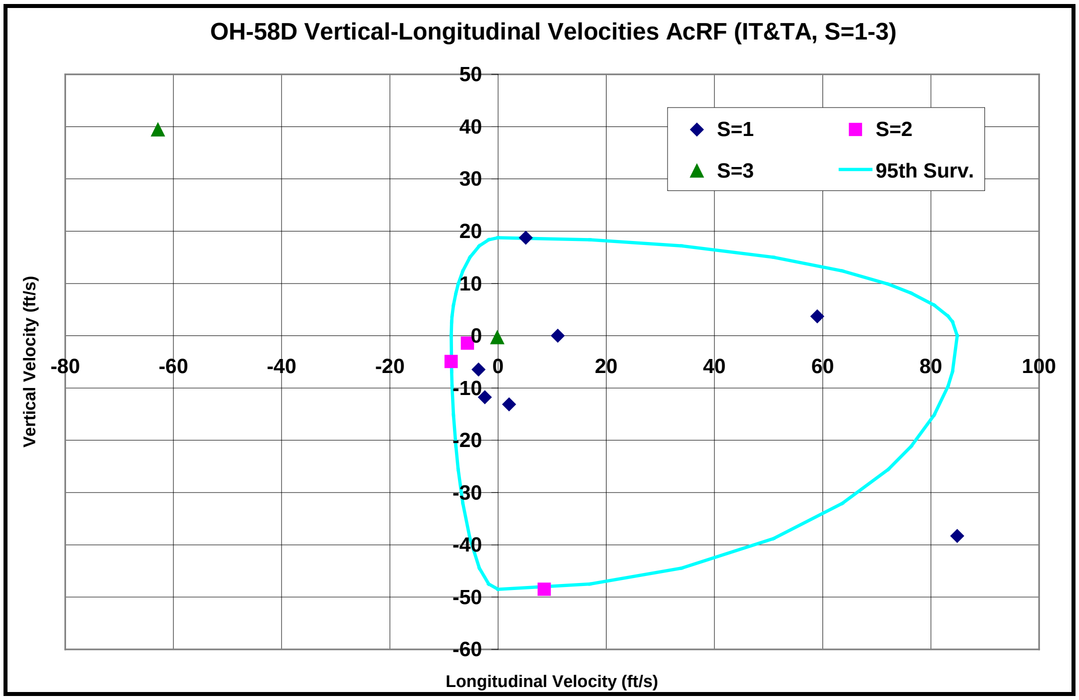

Figure C-34 – OH-58D Vertical-Longitudinal Velocities AcRF (IT&TA, S=1-3)

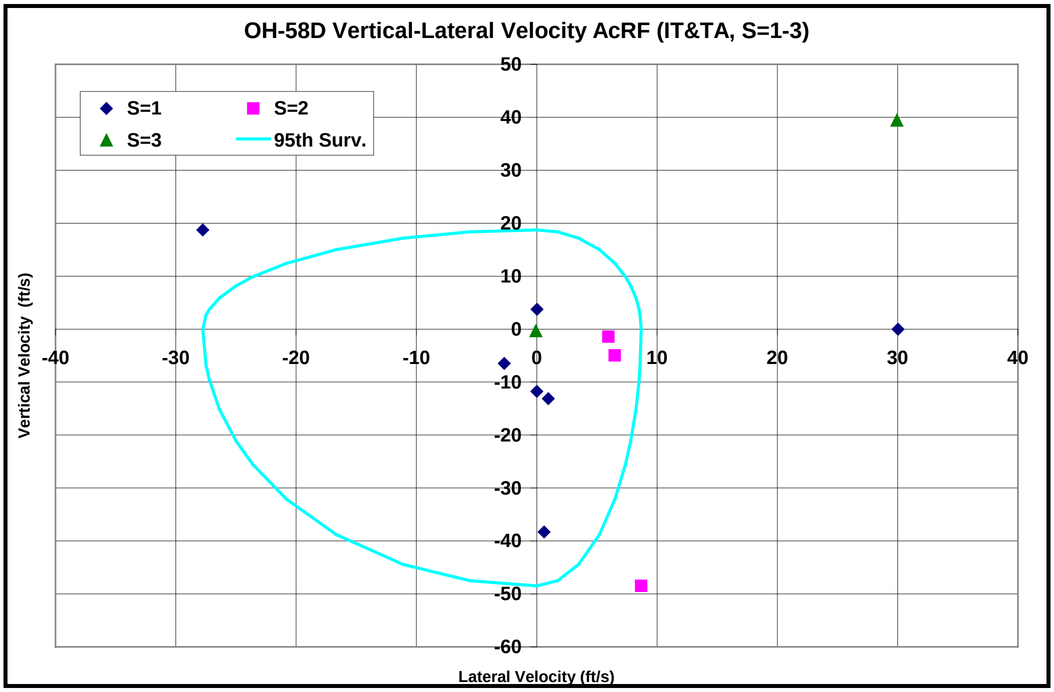

Figure C-35 – OH-58D Vertical-Lateral Velocity AcRF (IT&TA, S=1-3)

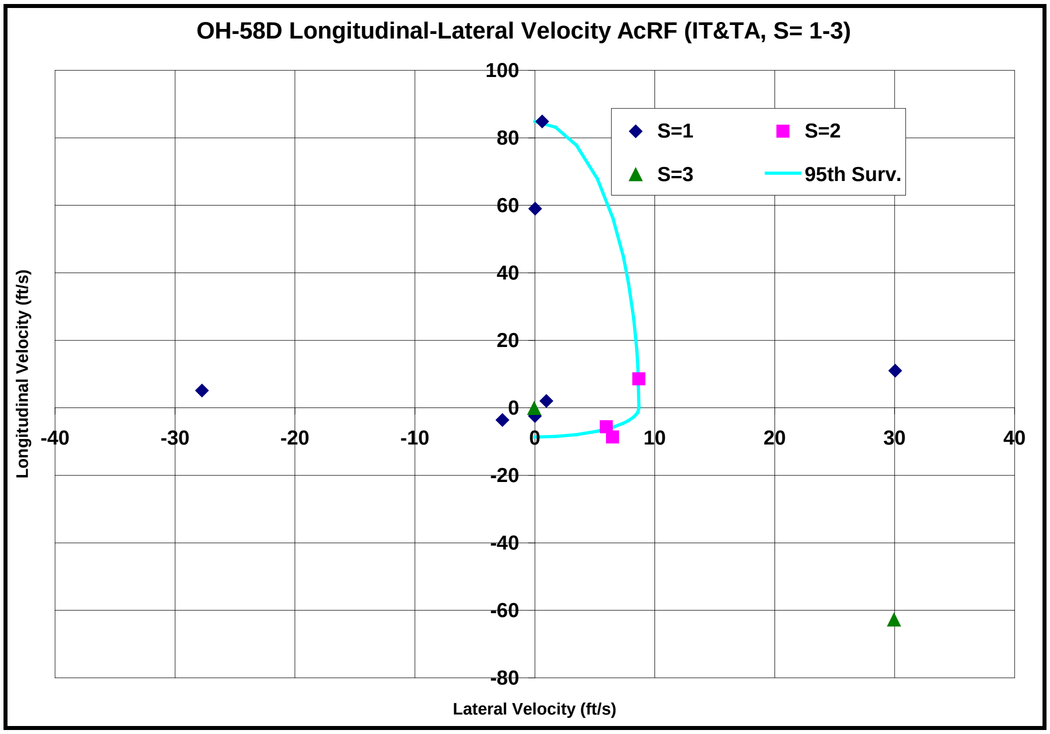

Figure C-36 – OH-58D Longitudinal-Lateral Velocity AcRF (IT&TA, S= 1-3)

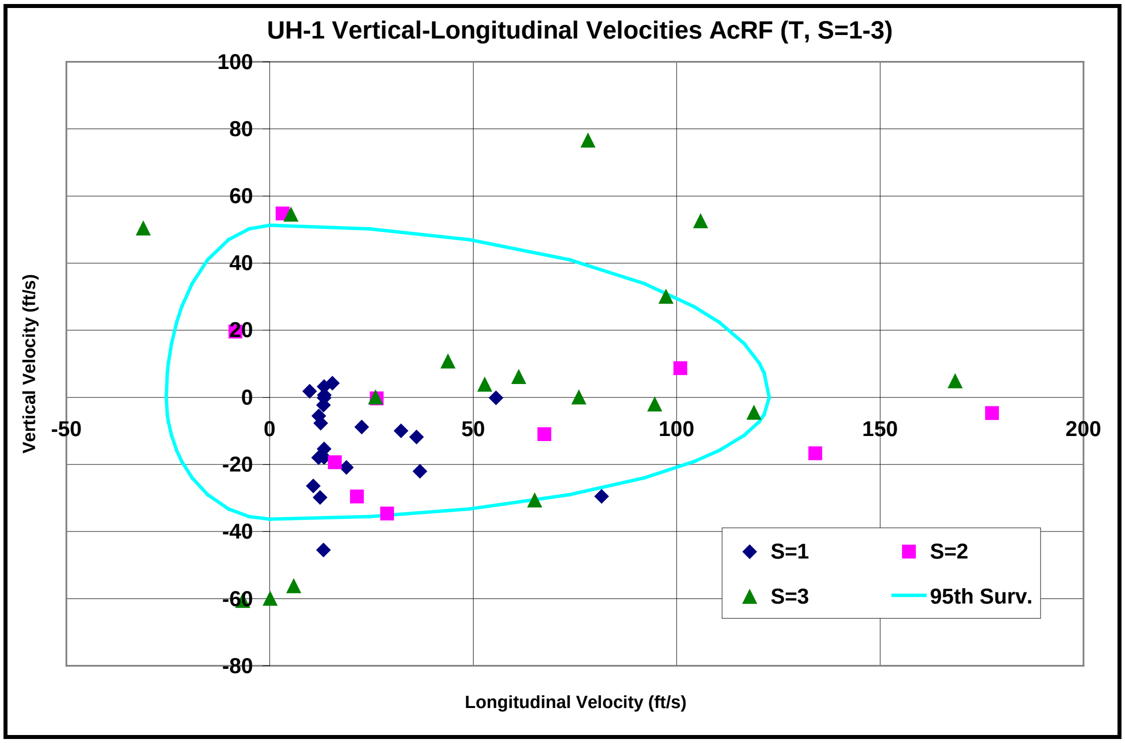

Figure C-37 – UH-1 Vertical-Longitudinal Velocities AcRF (T, S=1-3)

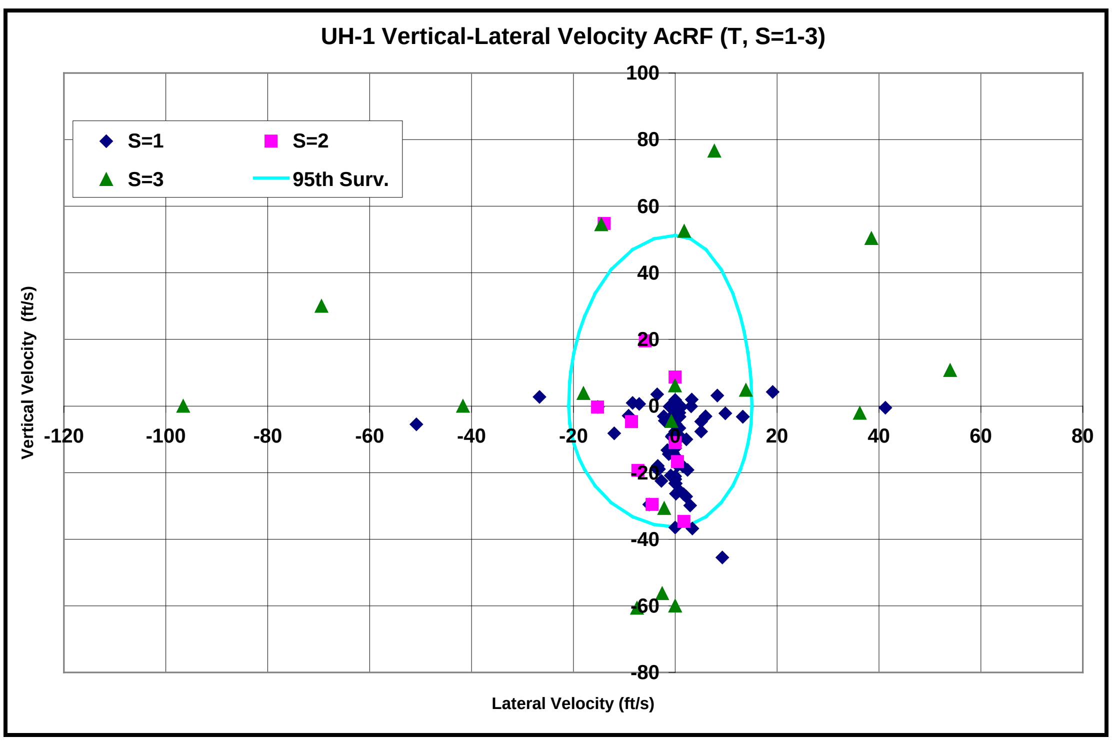

Figure C-38 – UH-1 Vertical-Lateral Velocity AcRF (T, S=1-3)

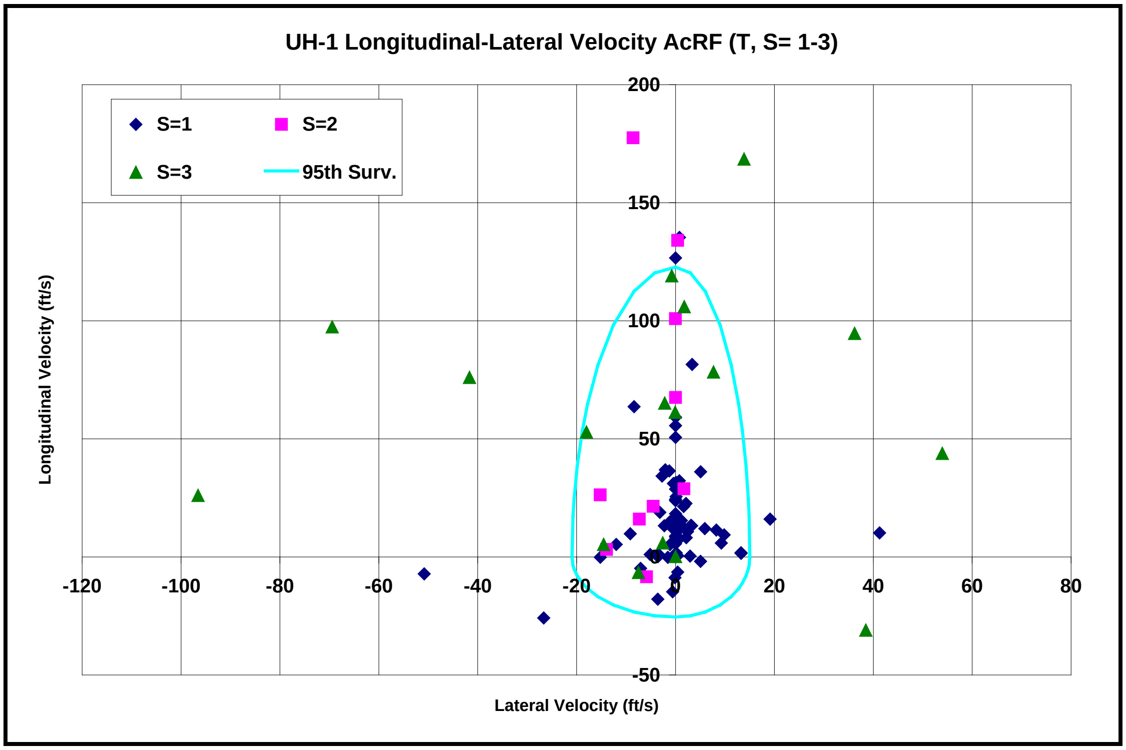

Figure C-39 – UH-1 Longitudinal-Lateral Velocity AcRF (T, S= 1-3)

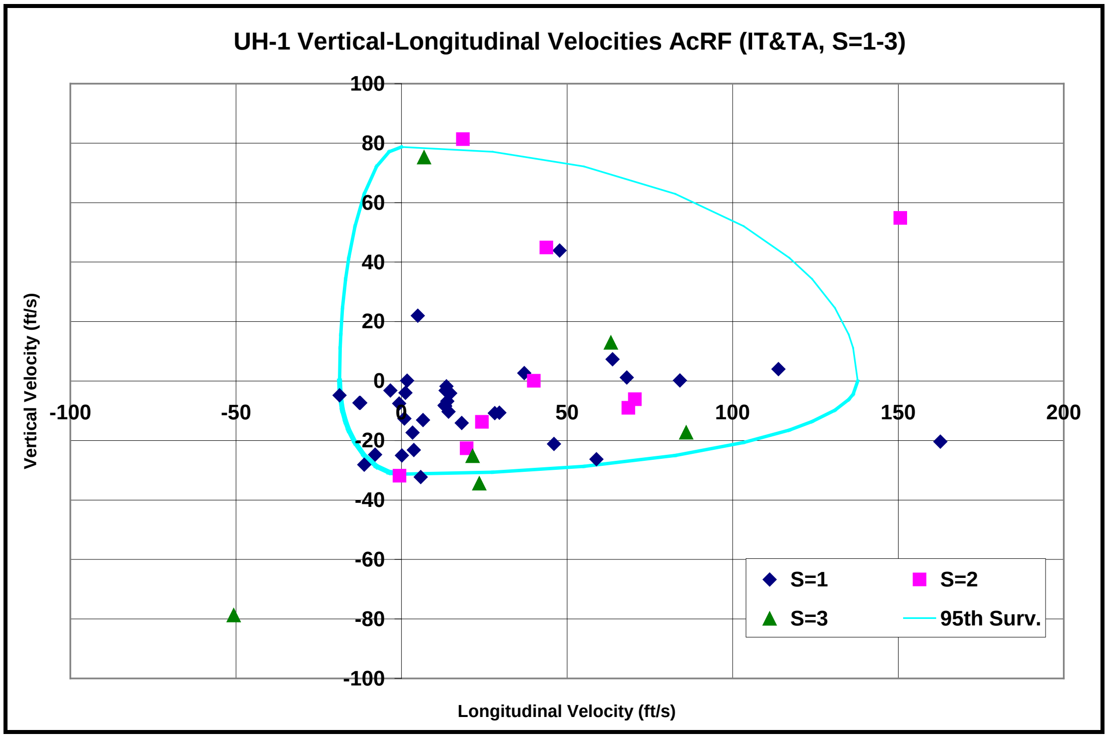

Figure C-40 – UH-1 Vertical-Longitudinal Velocities AcRF (IT&TA, S=1-3)

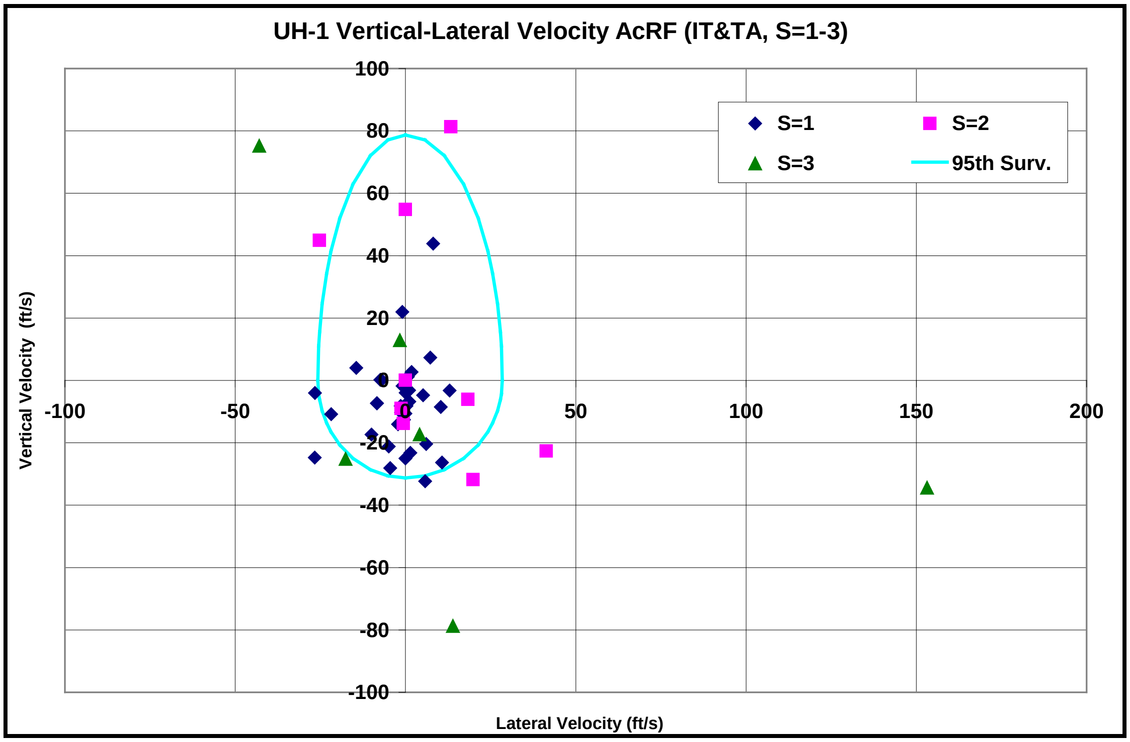

Figure C-41 – UH-1 Vertical-Lateral Velocity AcRF (IT&TA, S=1-3)

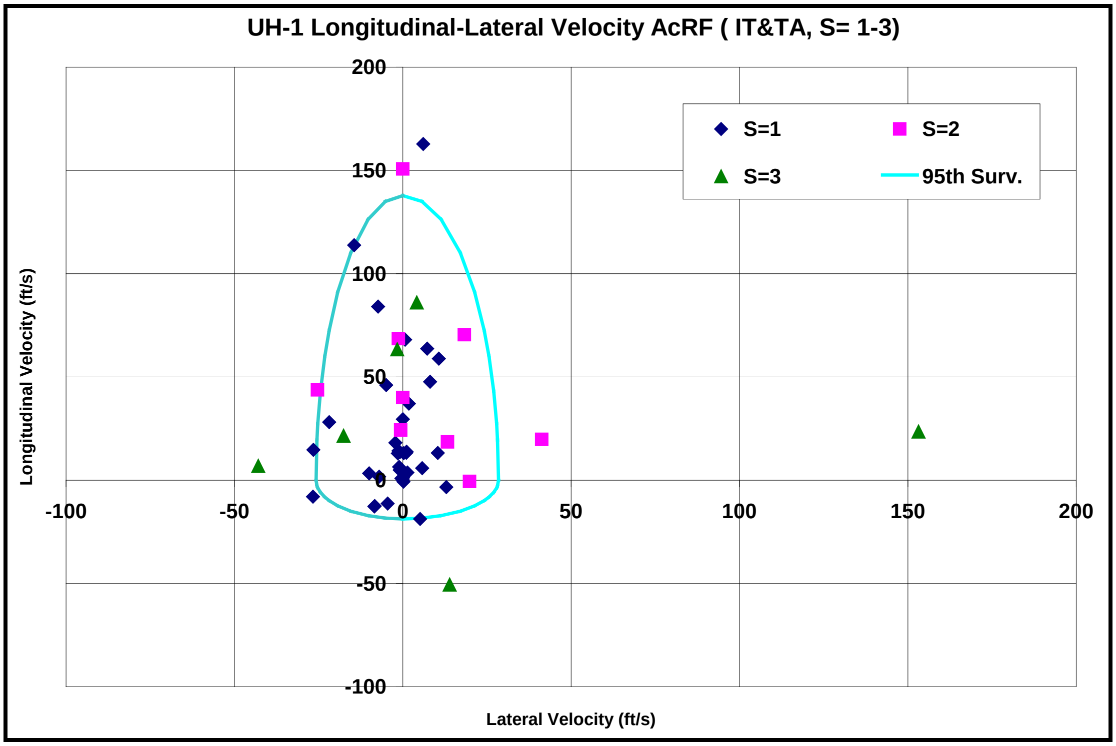

Figure C-42 – UH-1 Longitudinal-Lateral Velocity AcRF (IT&TA, S= 1-3)

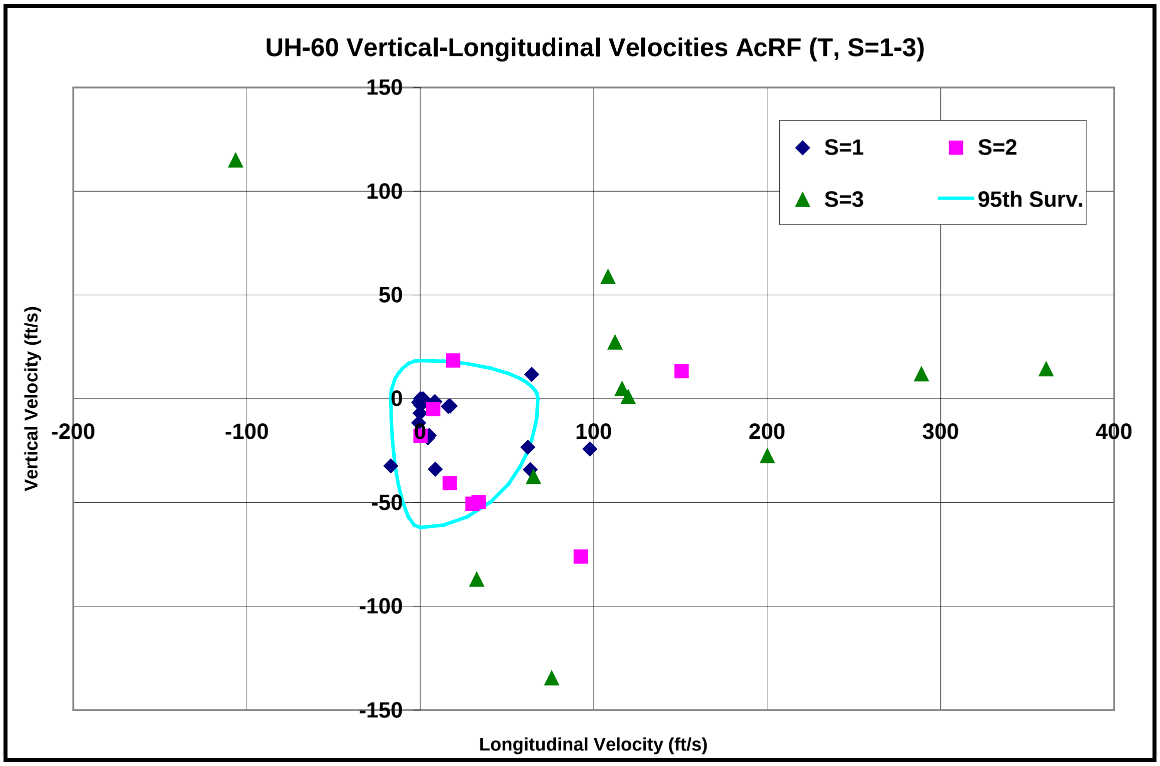

Figure C-43 – UH-60 Vertical-Longitudinal Velocities AcRF (T, S=1-3)

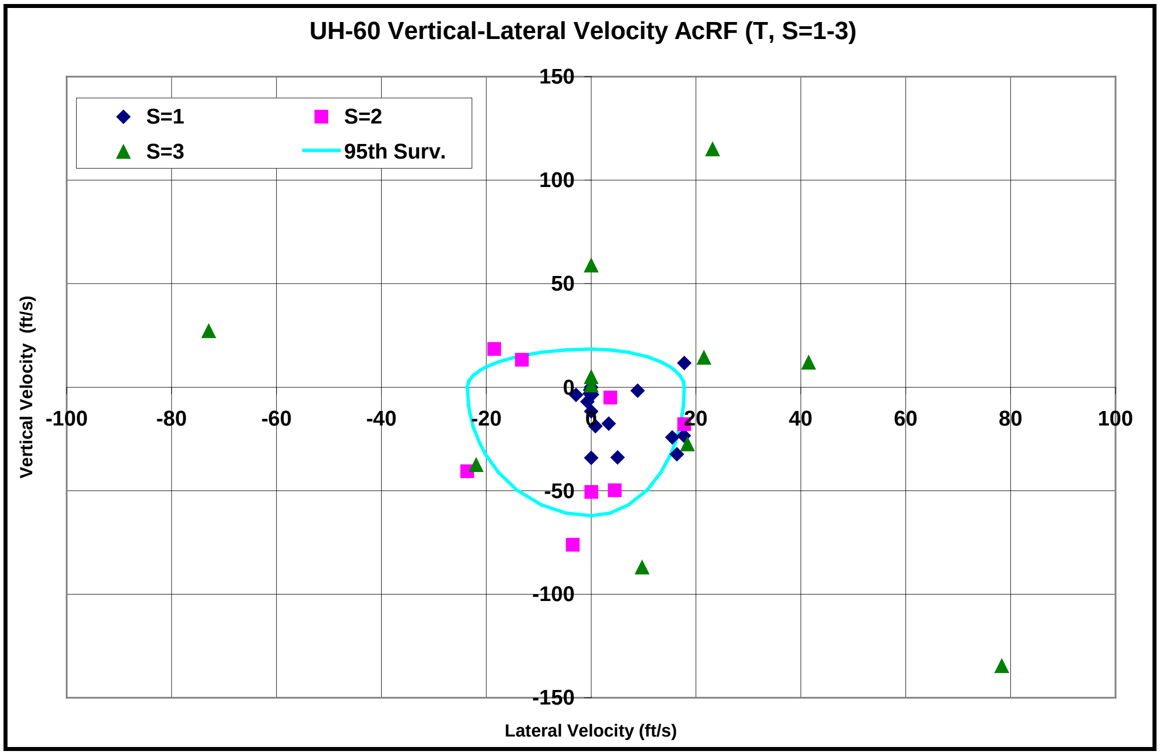

Figure C-44 – UH-60 Vertical-Lateral Velocity AcRF (T, S=1-3)

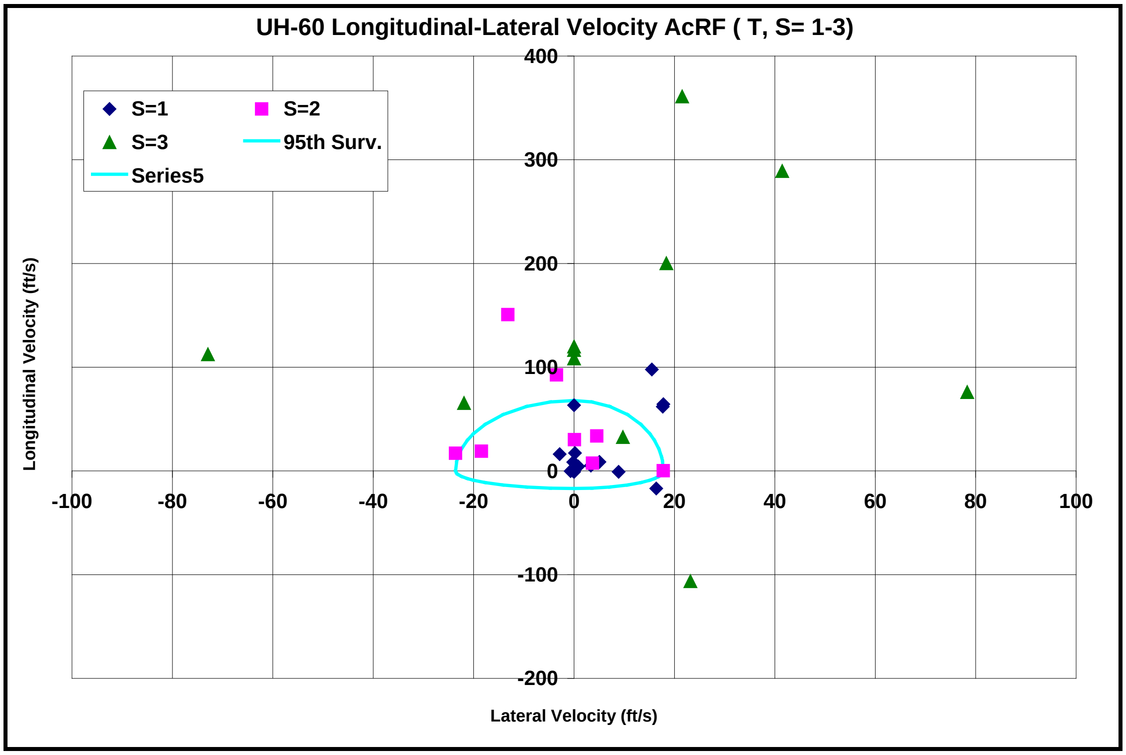

Figure C-45 – UH-60 Longitudinal-Lateral Velocity AcRF (T, S= 1-3)

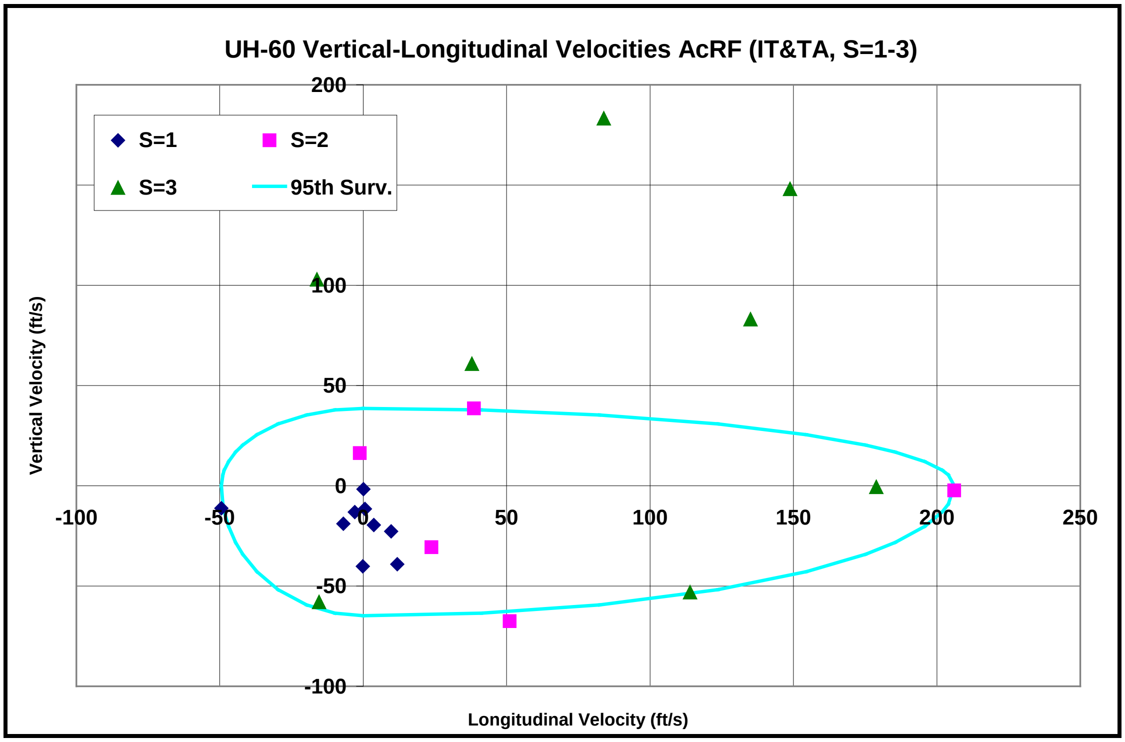

Figure C-46 – UH-60 Vertical-Longitudinal Velocities AcRF (IT&TA, S=1-3)

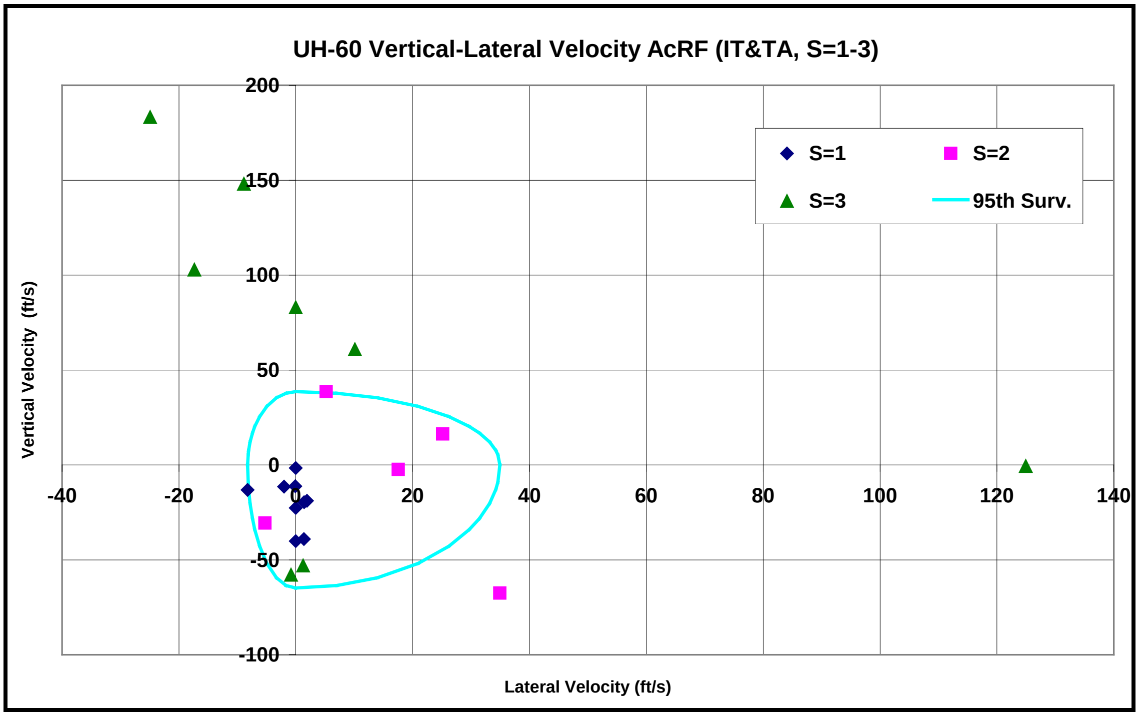

Figure C-47 – UH-60 Vertical-Lateral Velocity AcRF (IT&TA, S=1-3)

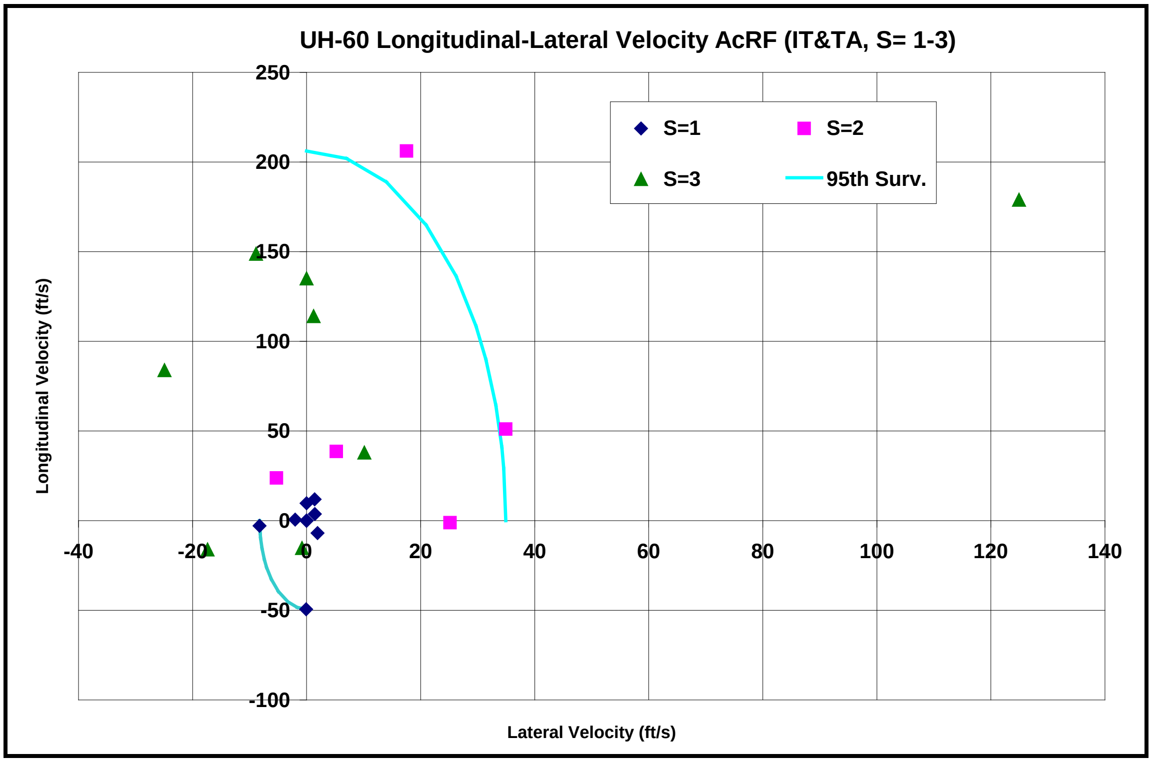

Figure C-48 – UH-60 Longitudinal-Lateral Velocity AcRF (IT&TA, S= 1-3)

Distribution: Unlimited

Appendix D – Impact Angles and Attitude Angle Plots

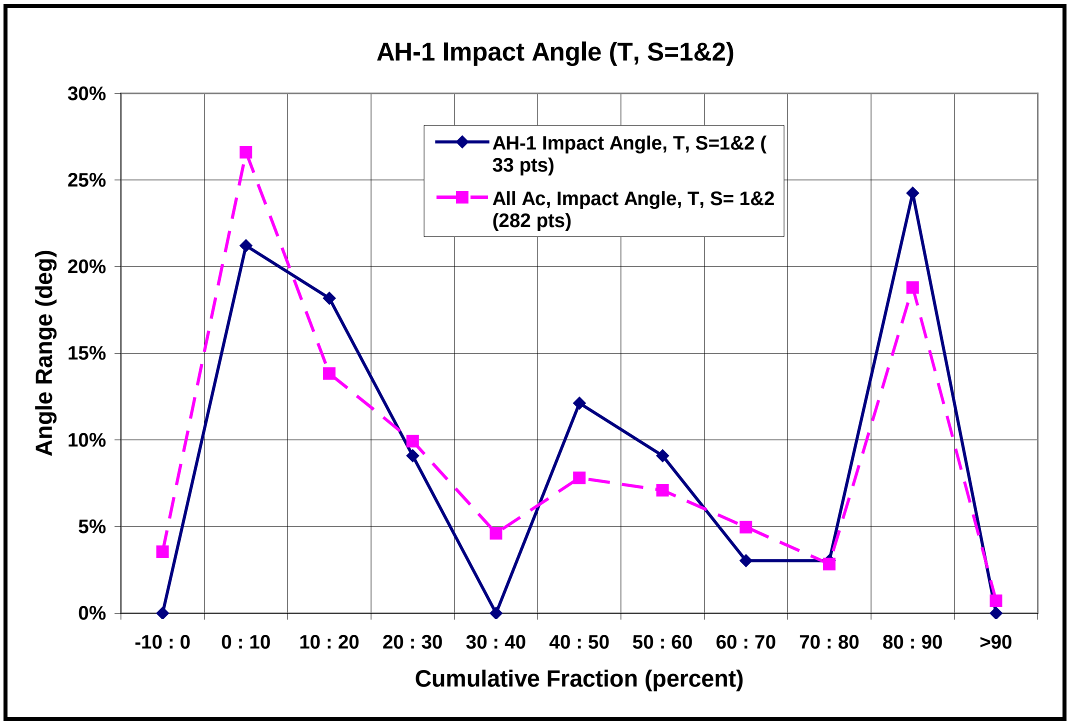

Figure D-1 – AH-1 Impact Angle (T, S=1&2)

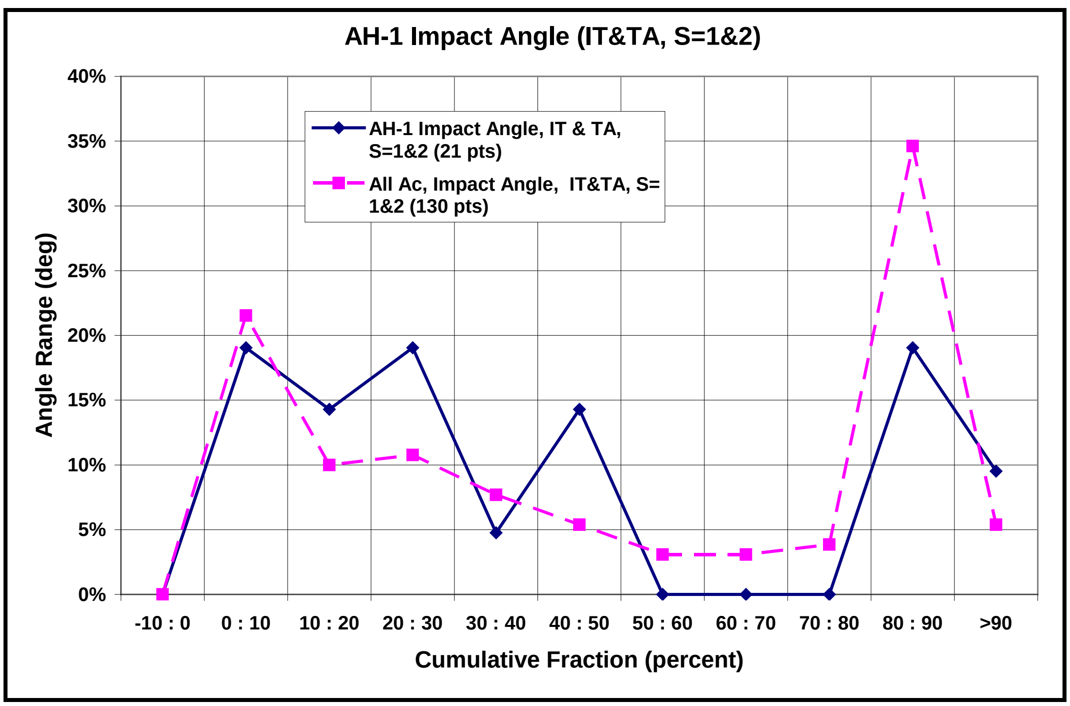

Figure D-2 – AH-1 Impact Angle (IT&TA, S=1&2)

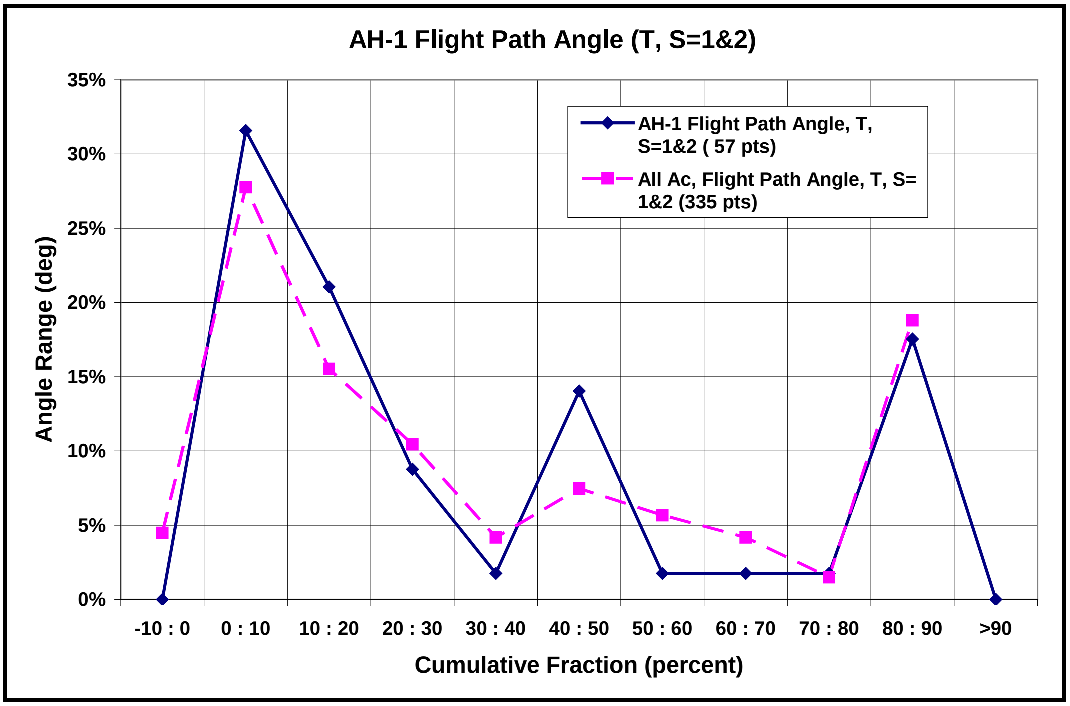

Figure D-3 – AH-1 Flight Path Angle (T, S=1&2)

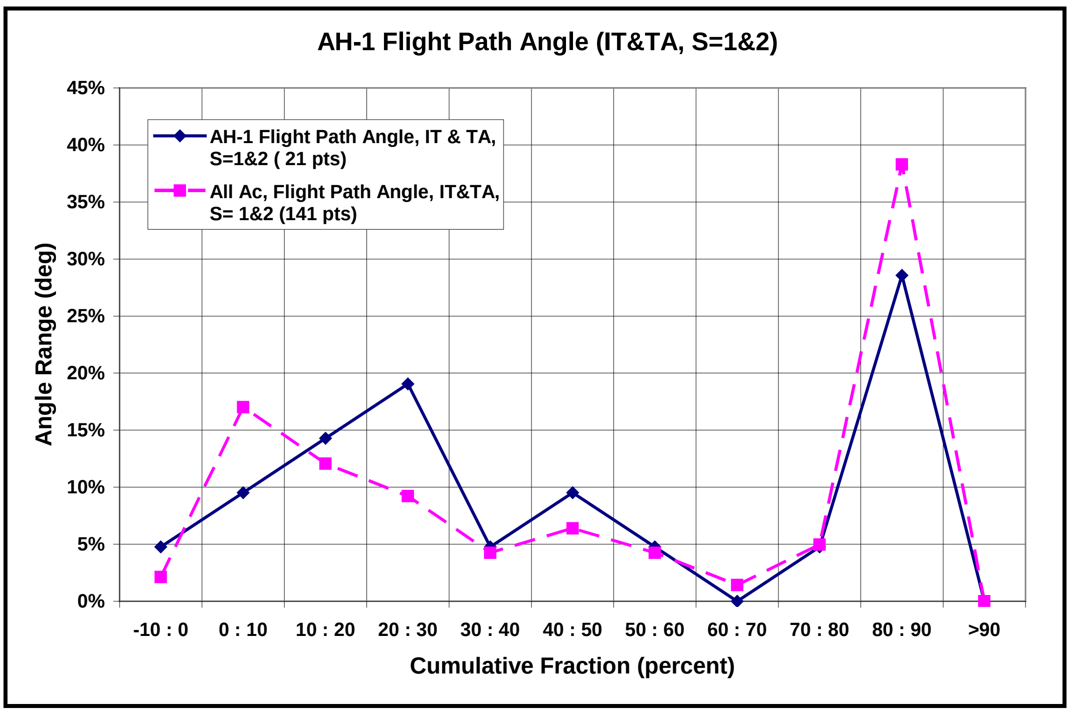

Figure D-4 – AH-1 Flight Path Angle (IT&TA, S=1&2)

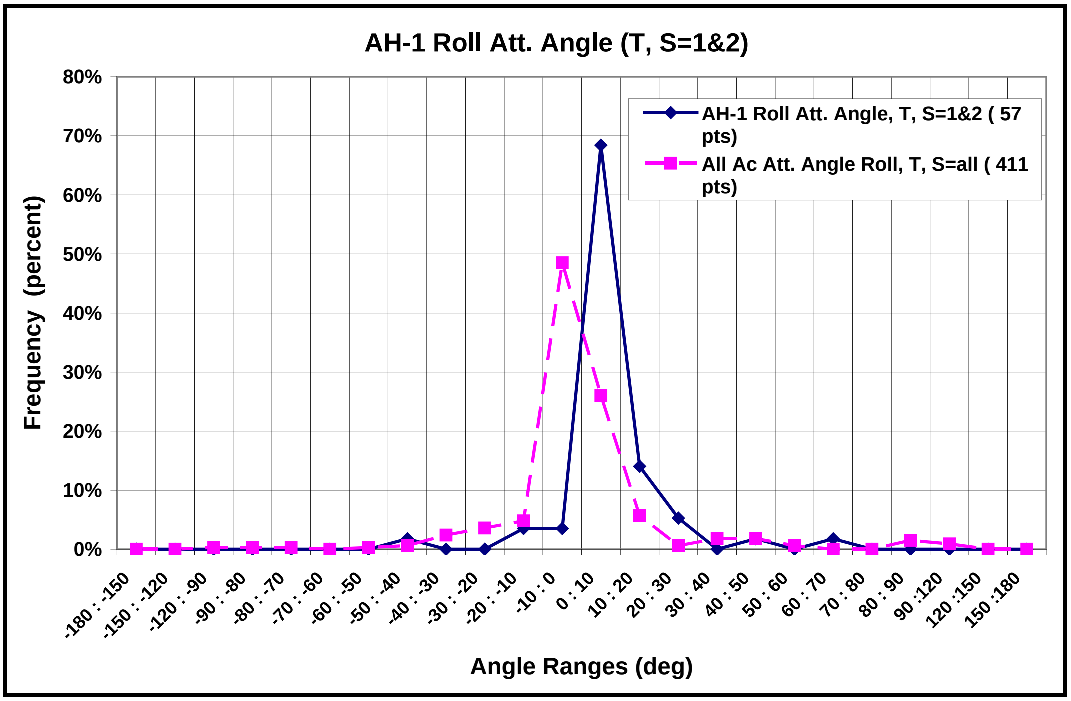

Figure D-5 – AH-1 Roll Attitude Angle (T, S=1&2)

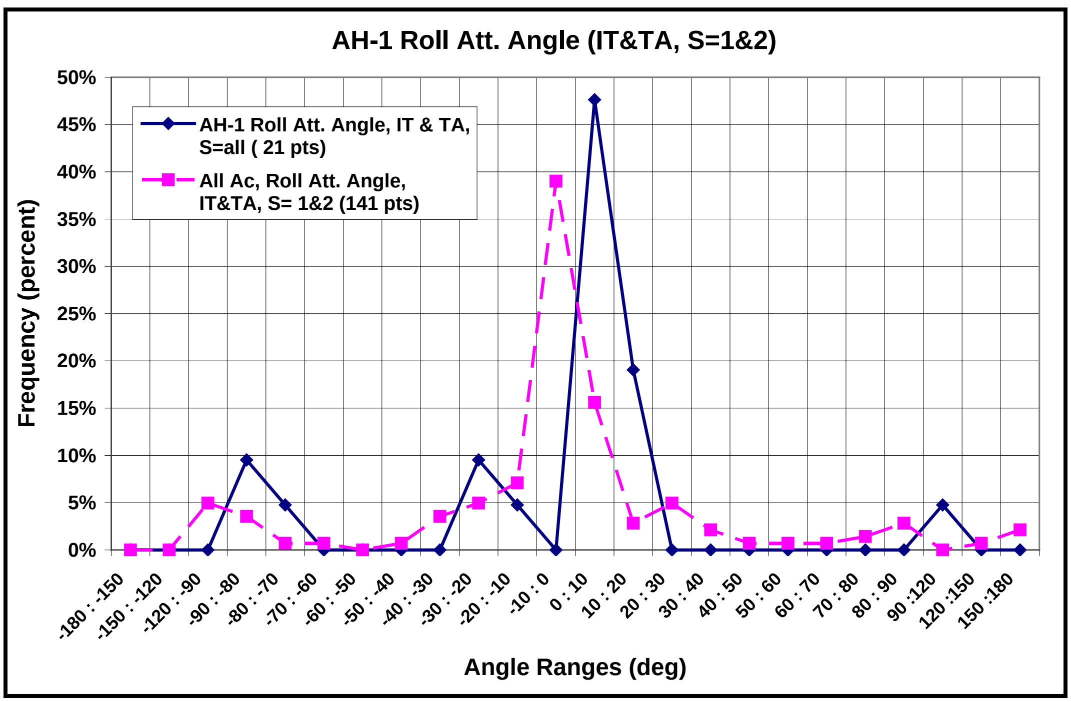

Figure D-6 – AH-1 Roll Attitude Angle (IT&TA, S=1&2)

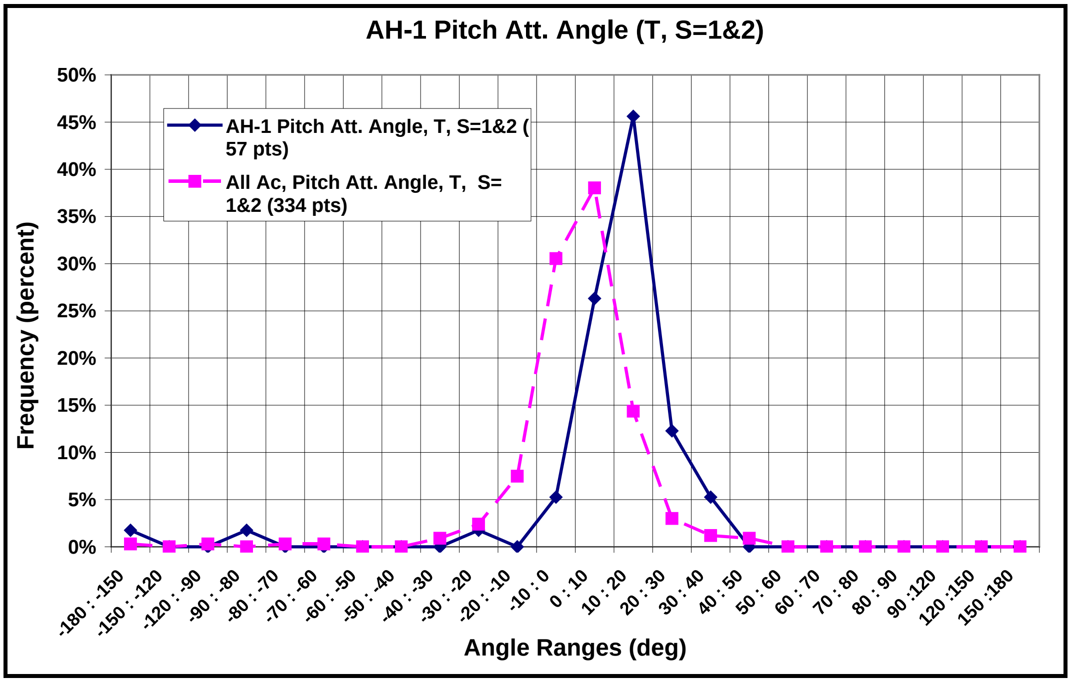

Figure D-7 – AH-1 Pitch Attitude Angle (T, S=1&2)

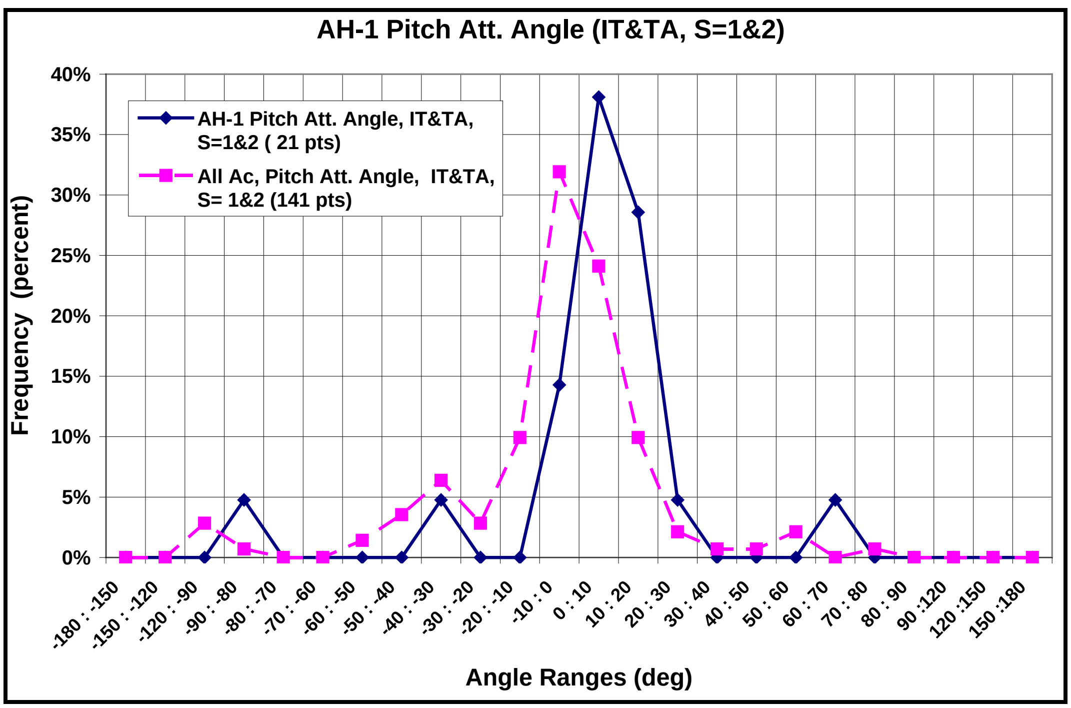

Figure D-8 – AH-1 Pitch Attitude Angle (IT&TA, S=1&2)

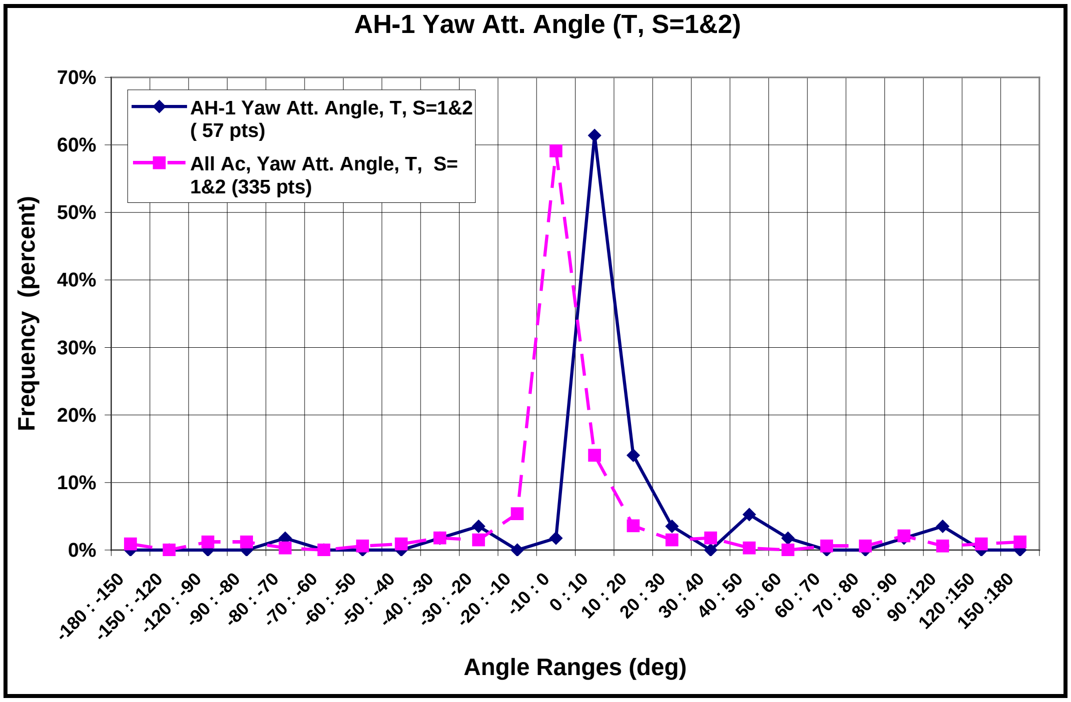

Figure D-9 – AH-1 Yaw Attitude Angle (T, S=1&2)

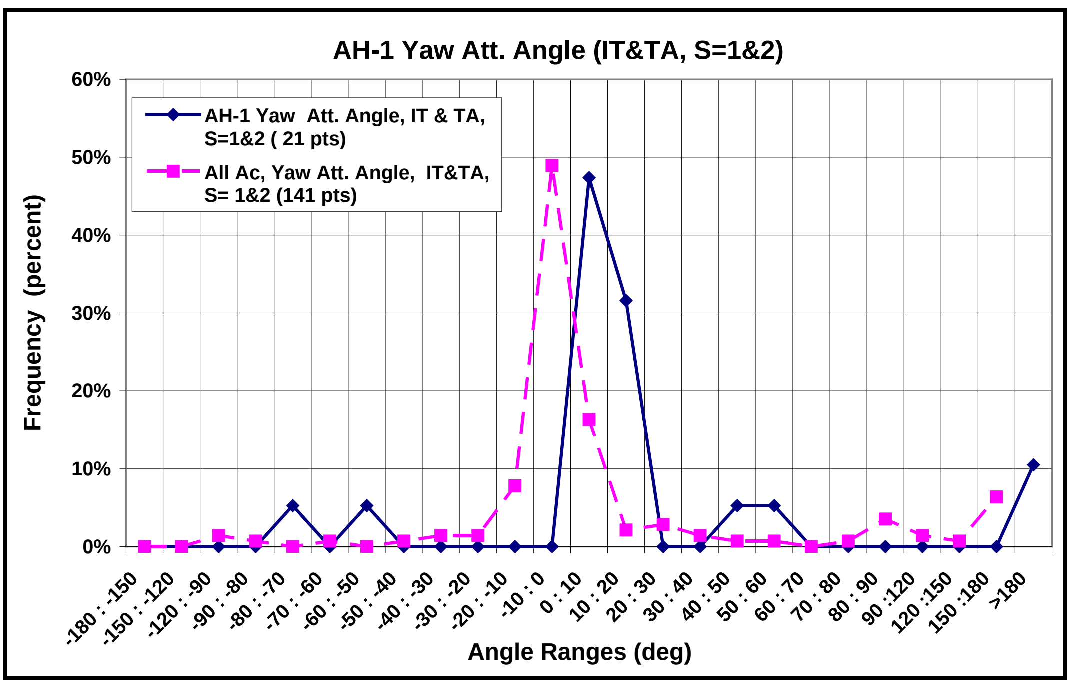

Figure D-10 – AH-1 Yaw Attitude Angle (IT&TA, S=1&2)

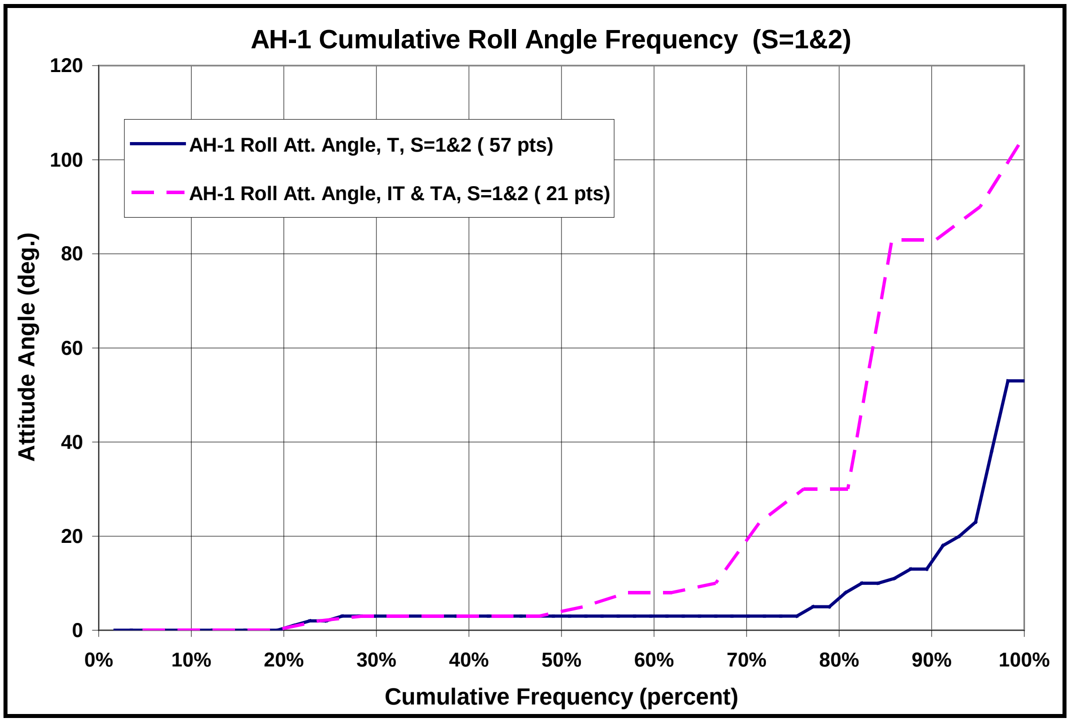

Figure D-11 – AH-1 Cumulative Roll Angle Frequency (S=1&2)

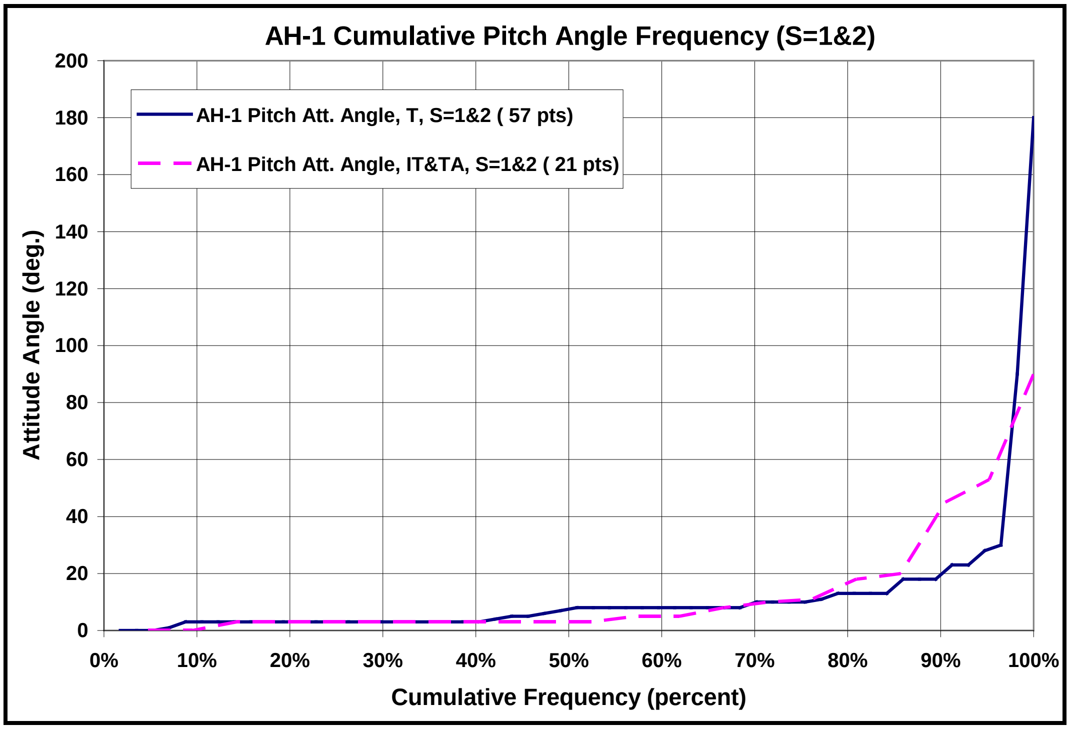

Figure D-12 – AH-1 Cumulative Pitch Angle Frequency (S=1&2)

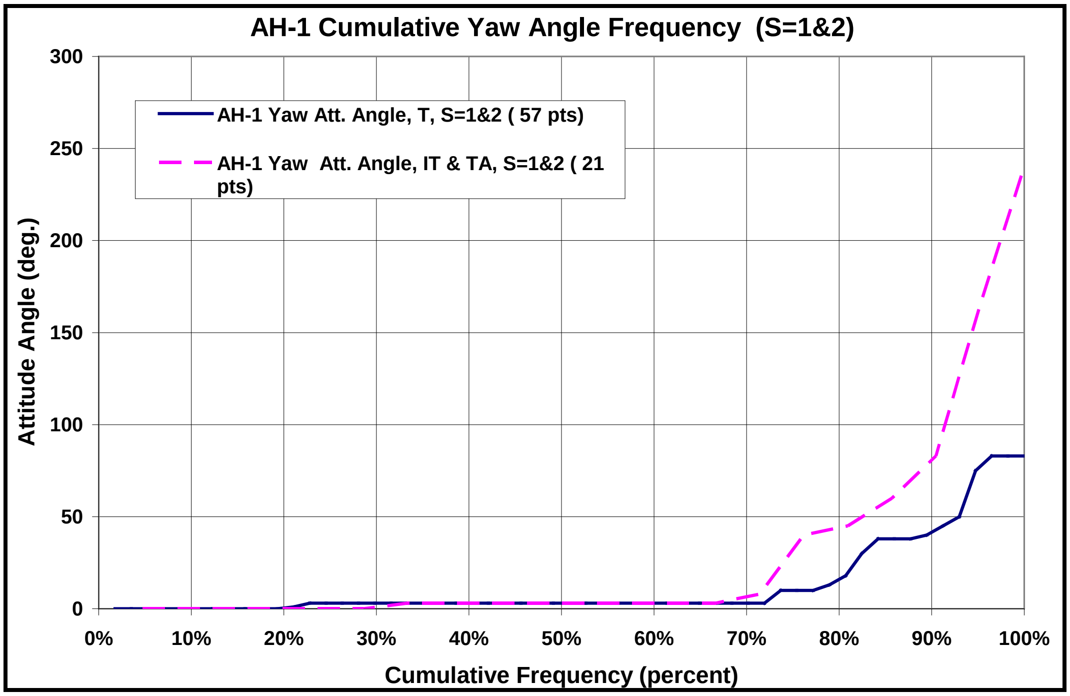

Figure D-13 – AH-1 Cumulative Yaw Angle Frequency (S=1&2)

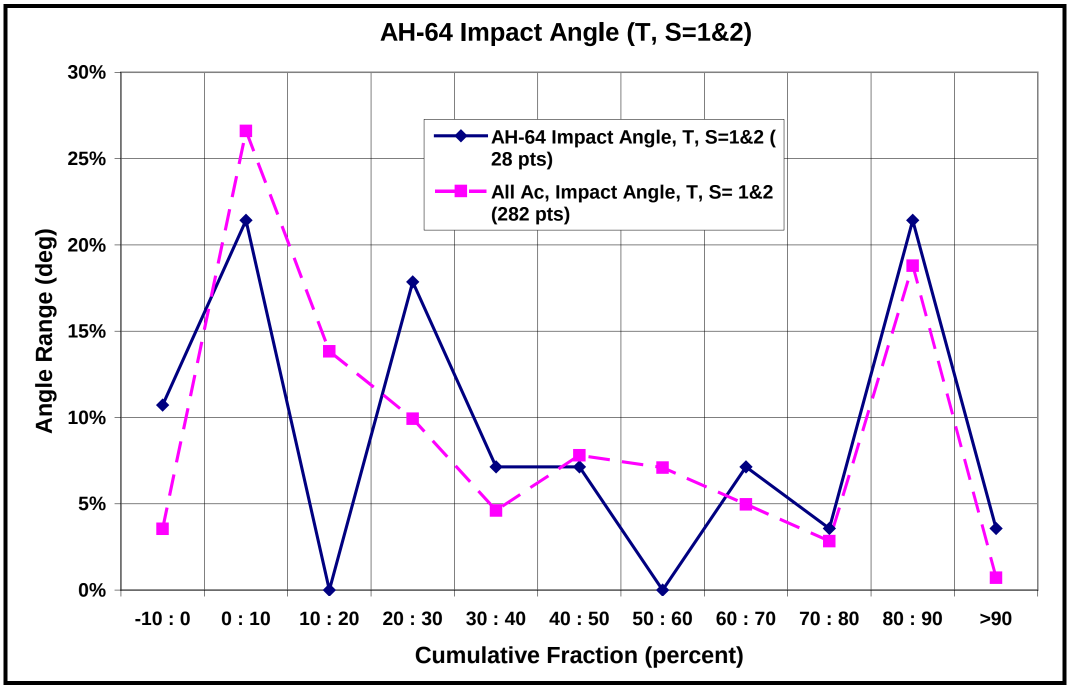

Figure D-14 – AH-64 Impact Angle (T, S=1&2)

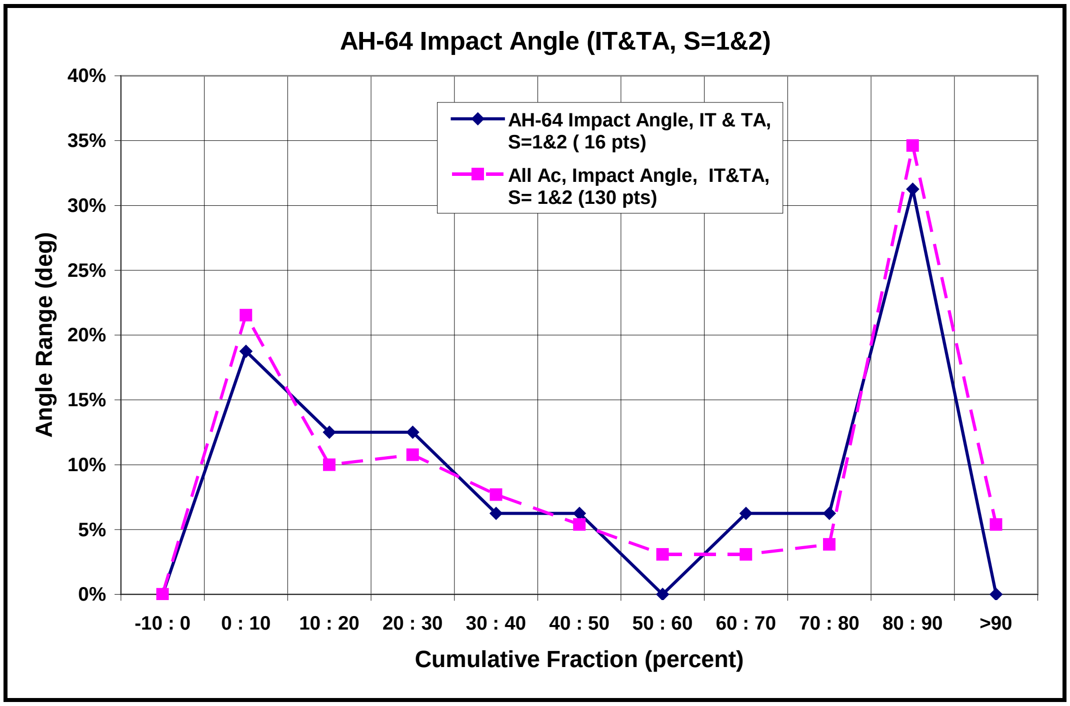

Figure D-15 – AH-64 Impact Angle (IT&TA, S=1&2)

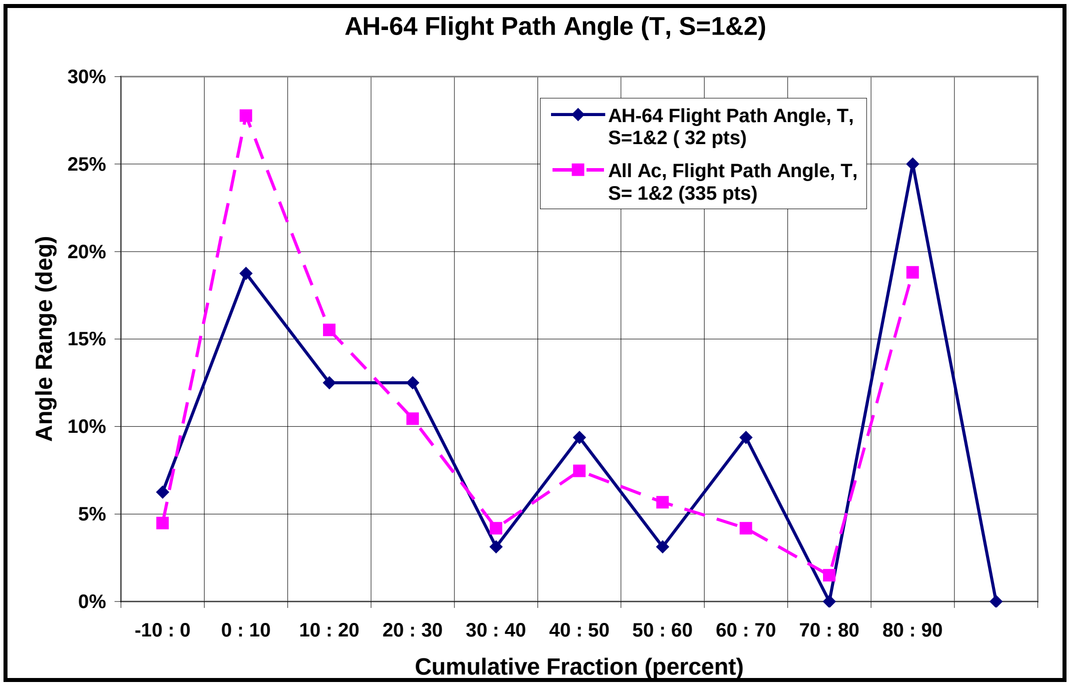

Figure D-16 – AH-64 Flight Path Angle (T, S=1&2)

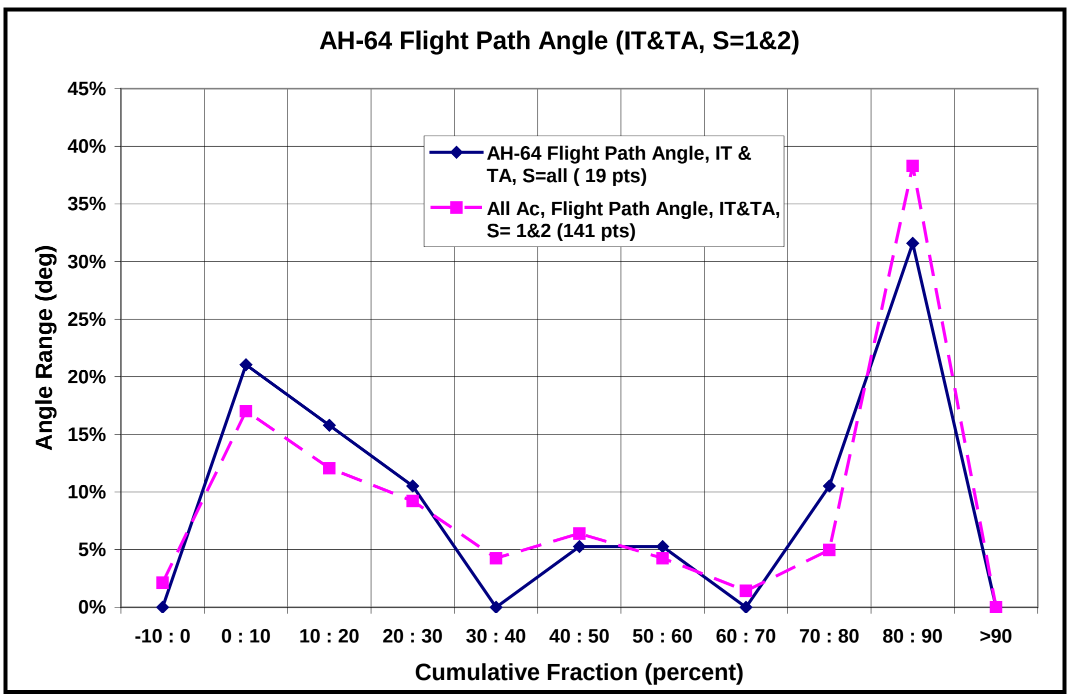

Figure D-17 – AH-64 Flight Path Angle (IT&TA, S=1&2)

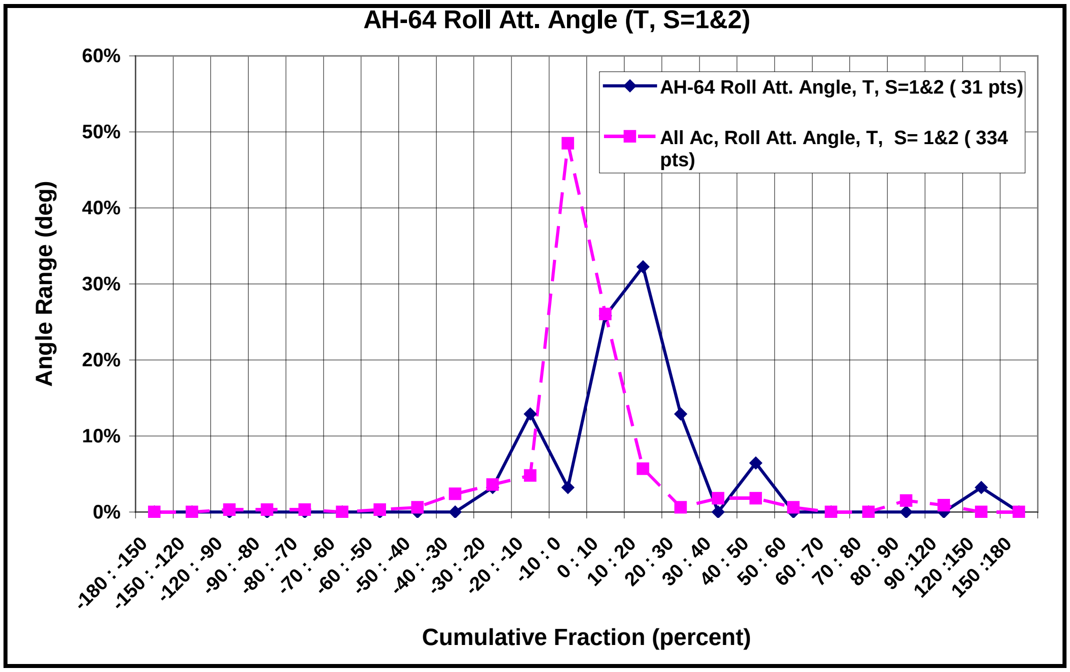

Figure D-18 – AH-64 Roll Attitude Angle (T, S=1&2)

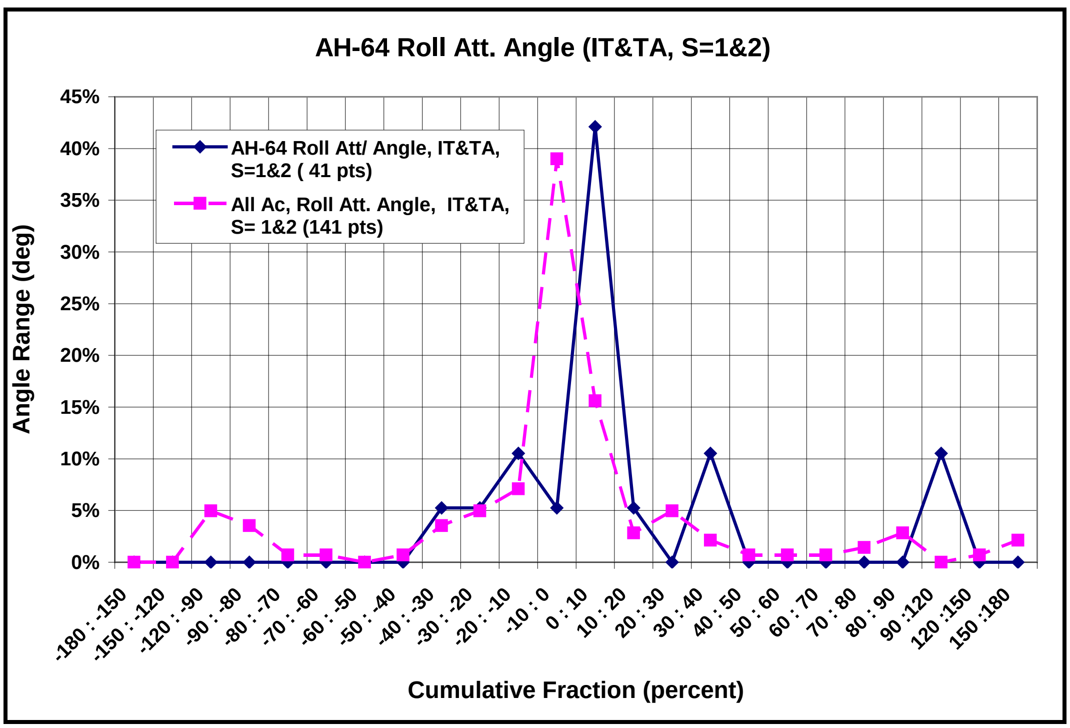

Figure D-19 – AH-64 Roll Attitude Angle (IT&TA, S=1&2)

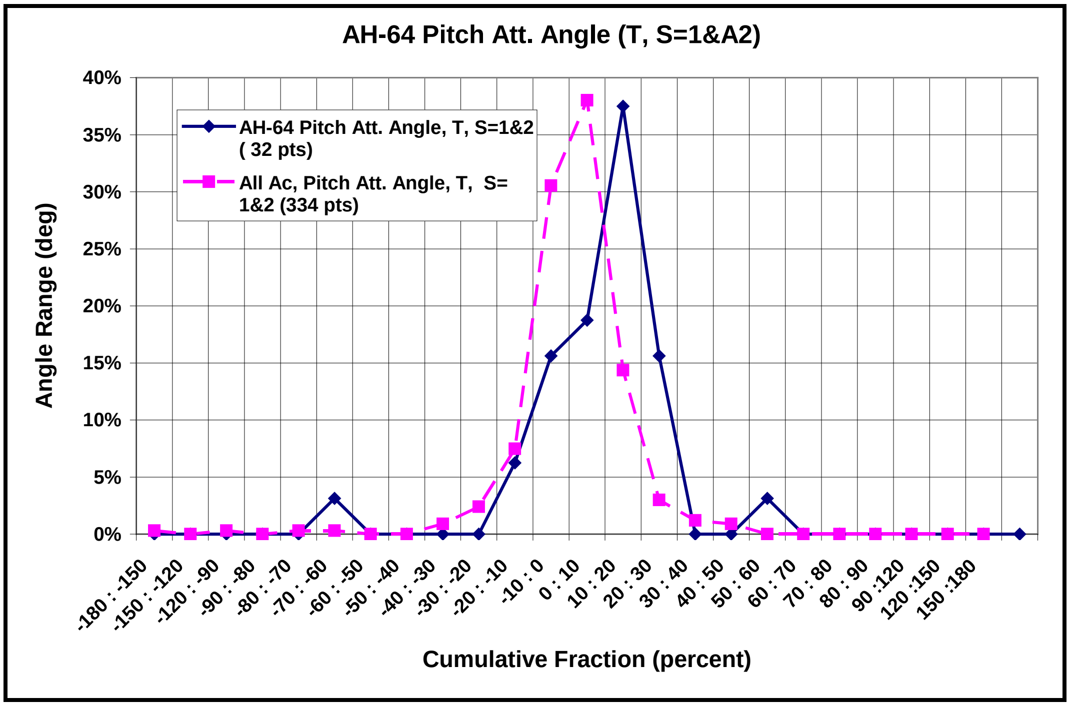

Figure D-20 – AH-64 Pitch Attitude Angle (T, S=1&2)

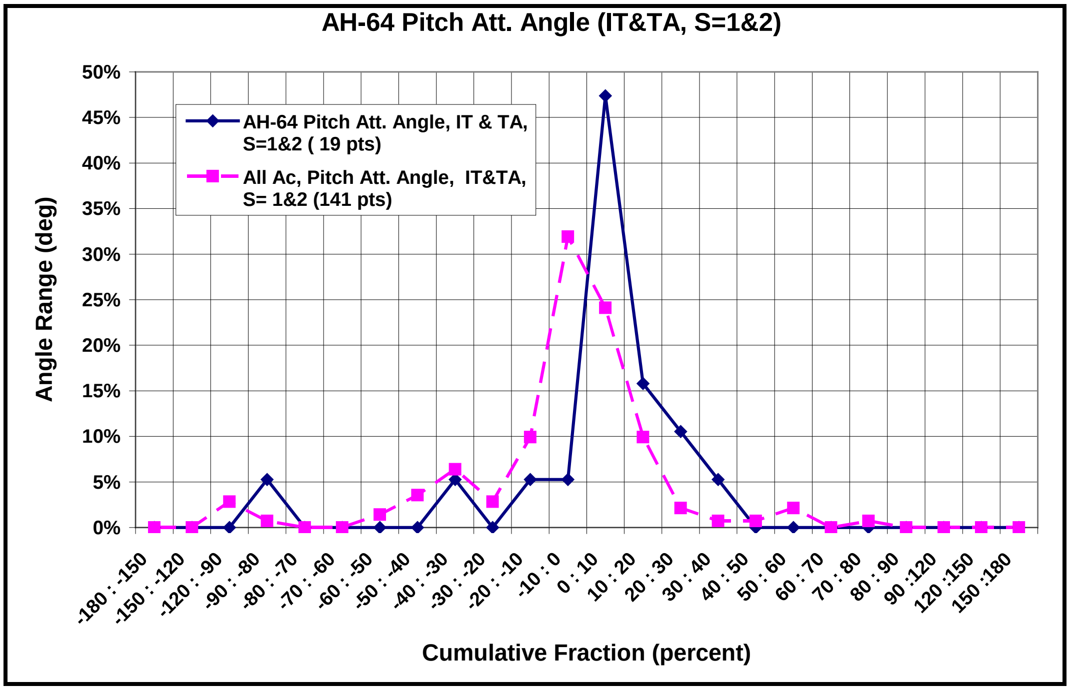

Figure D-21 – AH-64 Pitch Attitude Angle (IT&TA, S=1&2)

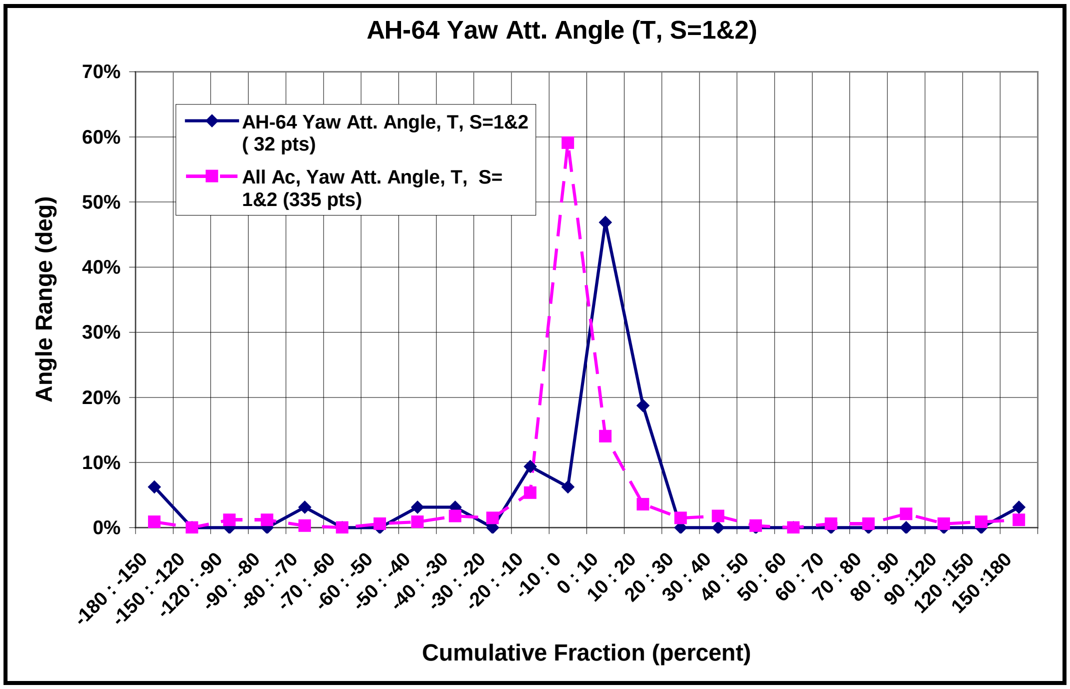

Figure D-22 – AH-64 Yaw Attitude Angle (T, S=1&2)

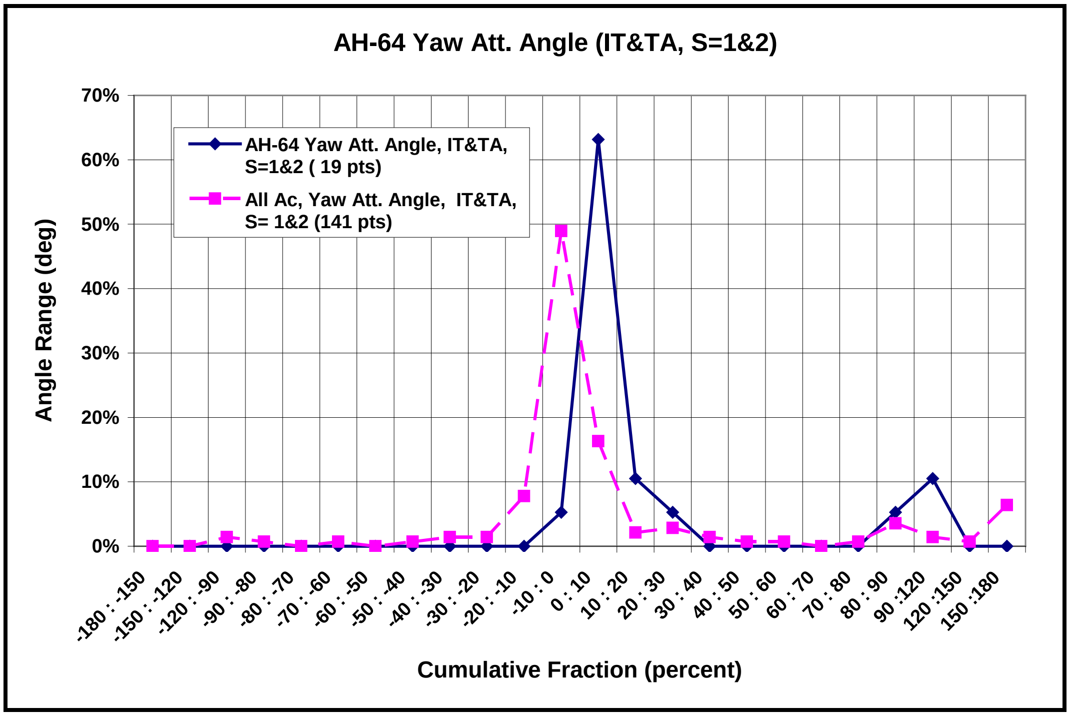

Figure D-23 – AH-64 Yaw Attitude Angle (IT&TA, S=1&2)

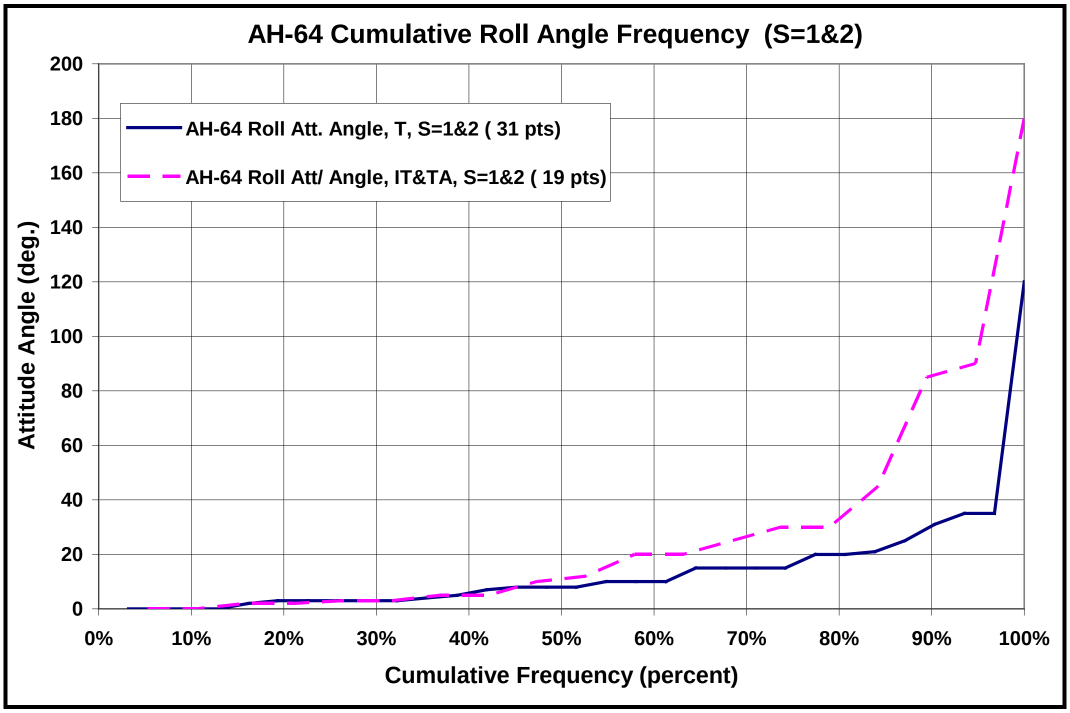

Figure D-24 – AH-64 Cumulative Roll Angle Frequency (S=1&2)

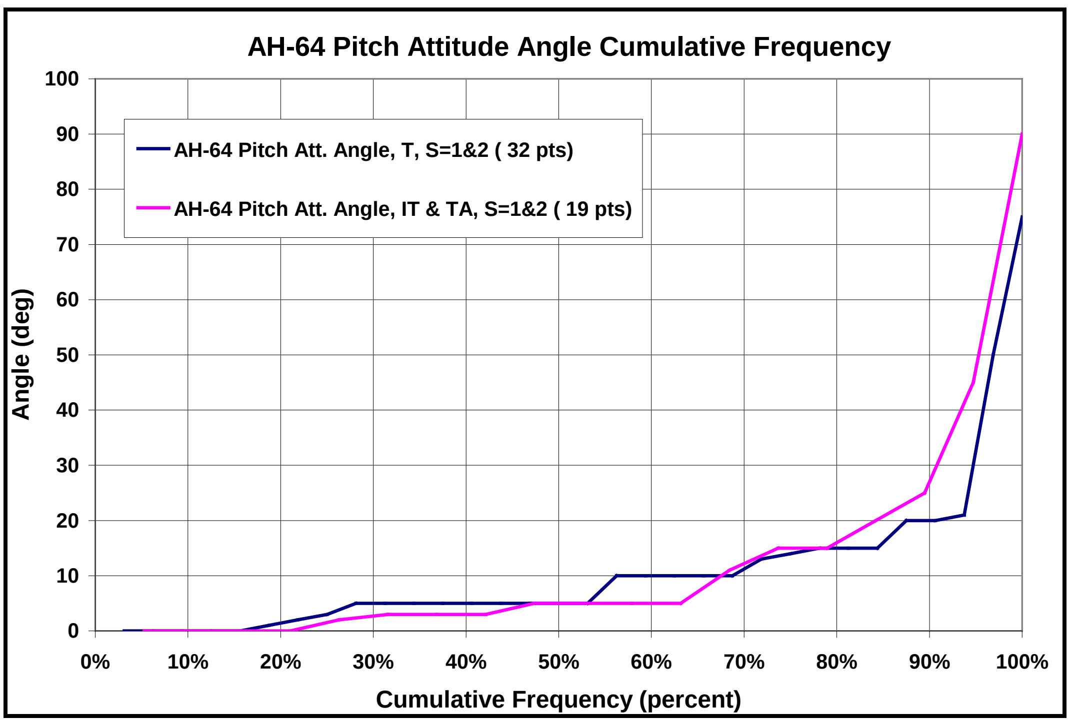

Figure D-25 – AH-64 Pitch Attitude Angle Cumulative Frequency

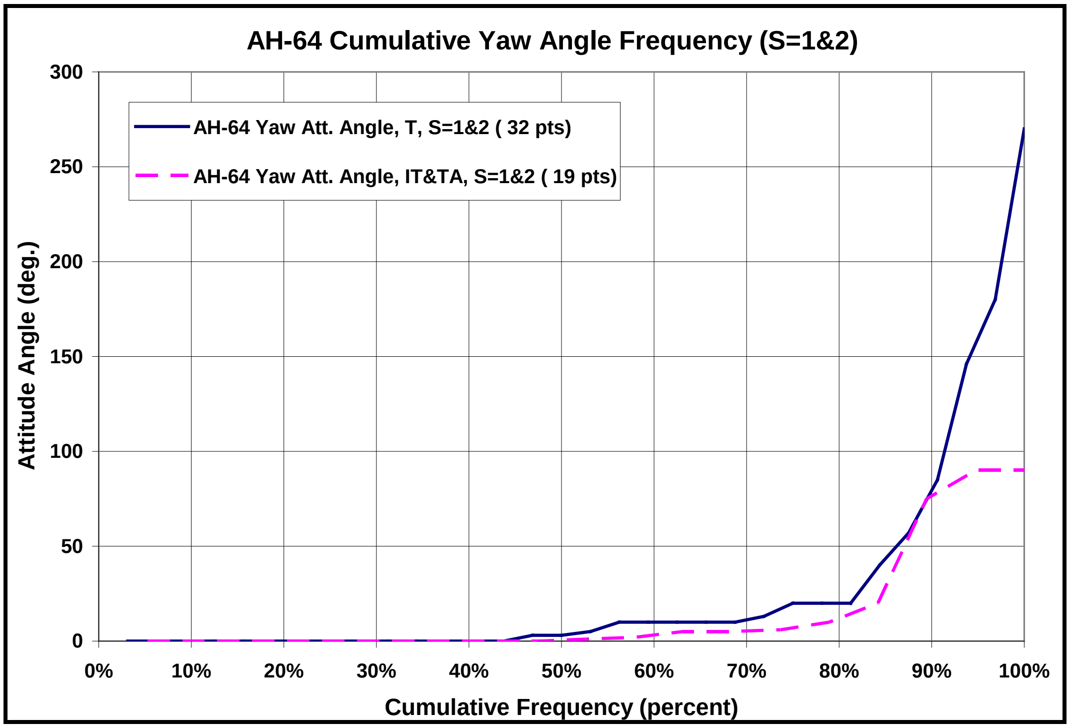

Figure D-26 – AH-64 Cumulative Yaw Angle Frequency (S=1&2)

Note: There were too few IT&TA mishaps to plot the angle data for the CH-47.

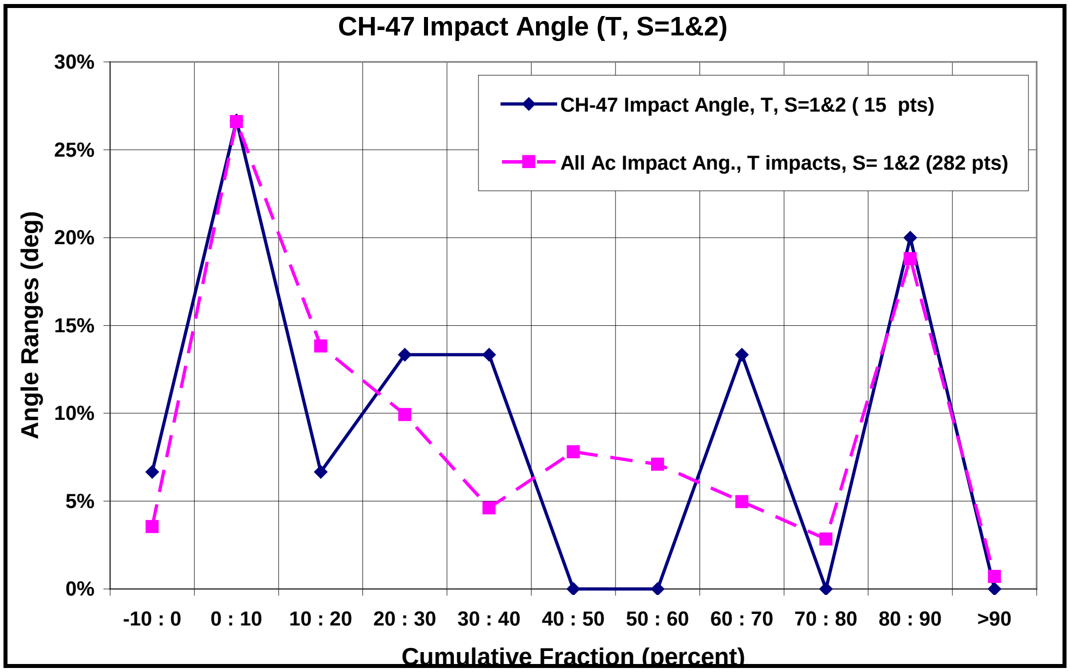

Figure D-27 – CH-47 Impact Angle (T, S=1&2)

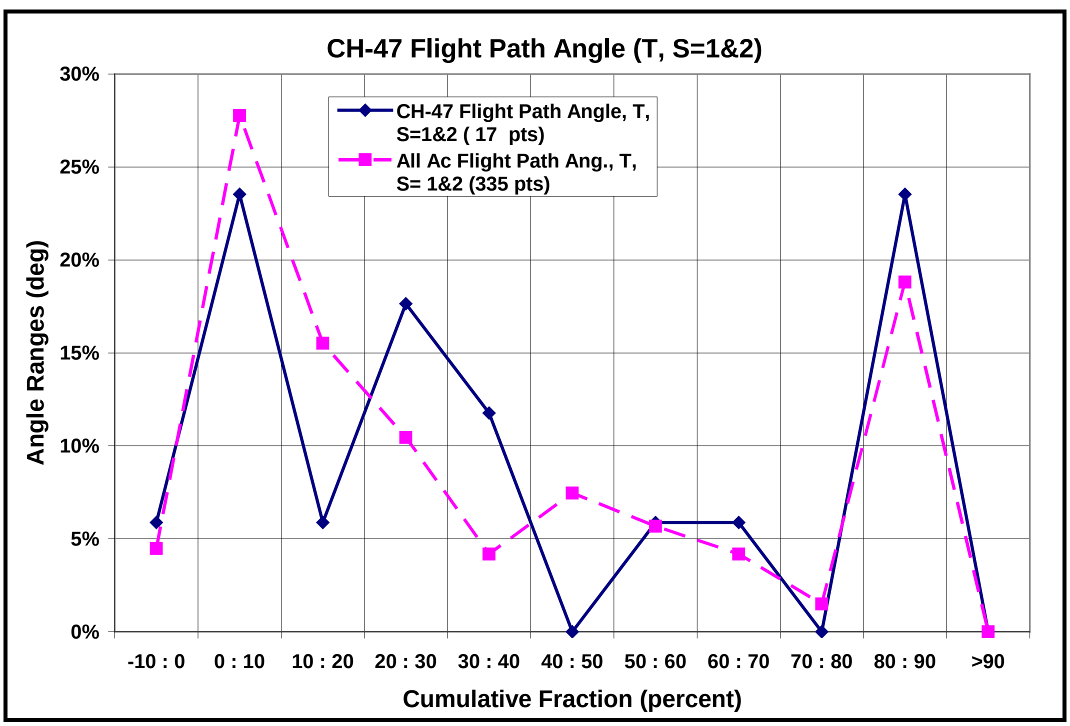

Figure D-28 – CH-47 Flight Path Angle (T, S=1&2)

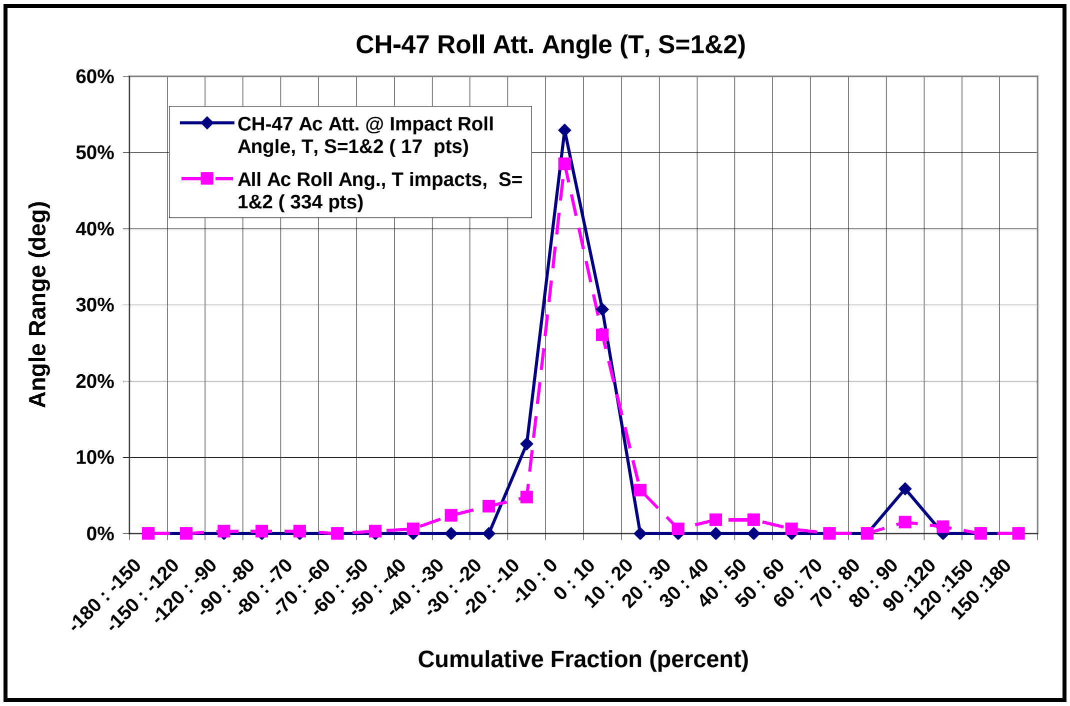

Figure D-29 – CH-47 Roll Attitude Angle (T, S=1&2)

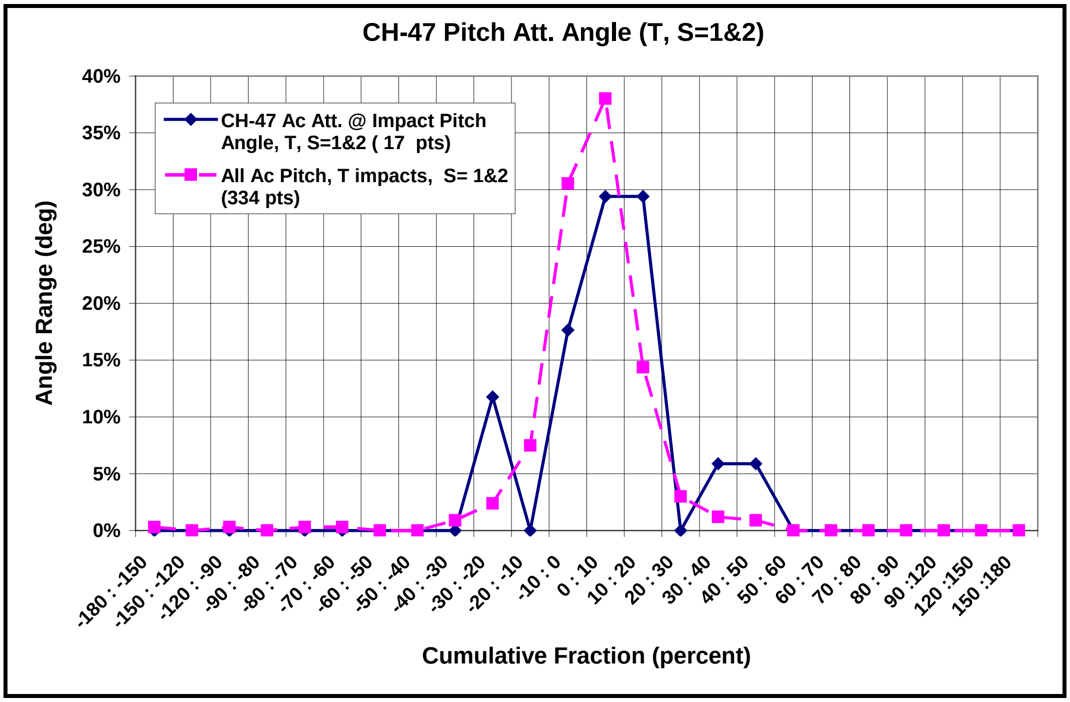

Figure D-30 – CH-47 Pitch Attitude Angle (T, S=1&2)

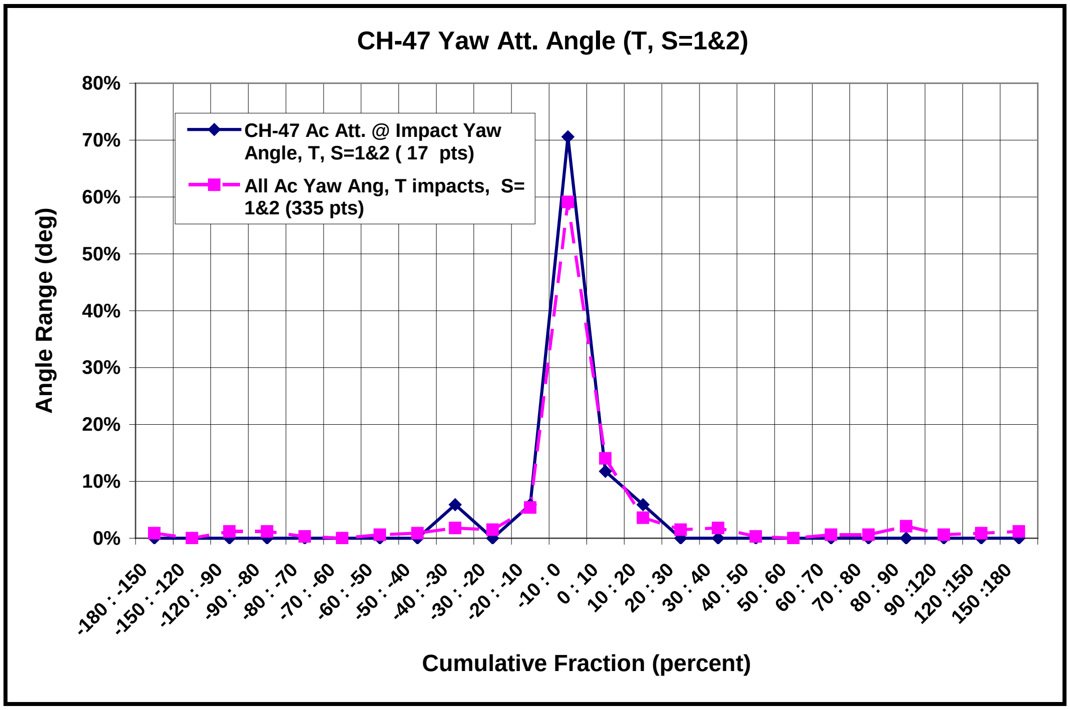

Figure D-31 – CH-47 Yaw Attitude Angle (T, S=1&2)

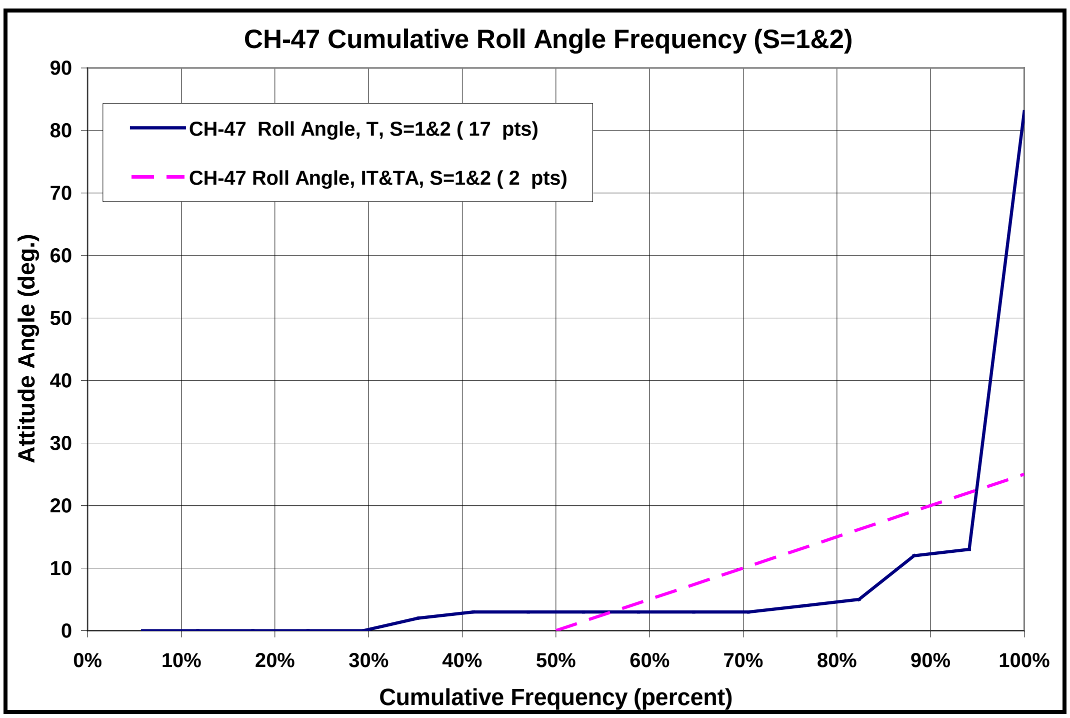

Figure D-32 – CH-47 Cumulative Roll Angle Frequency (S=1&2)

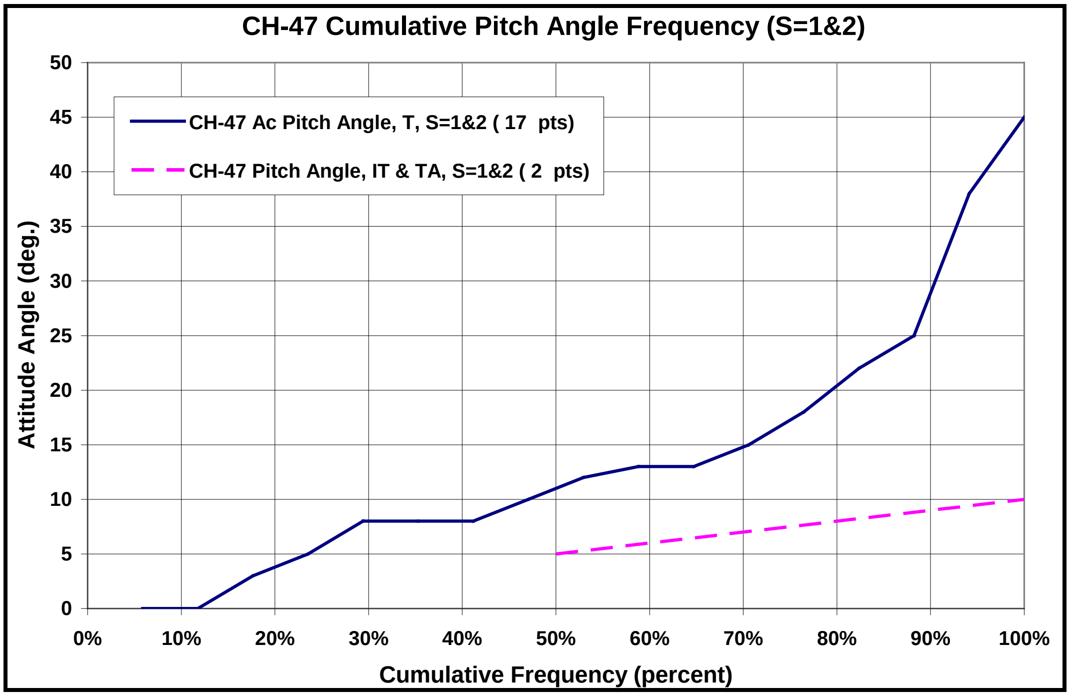

Figure D-33 – CH-47 Cumulative Pitch Angle Frequency (S=1&2)

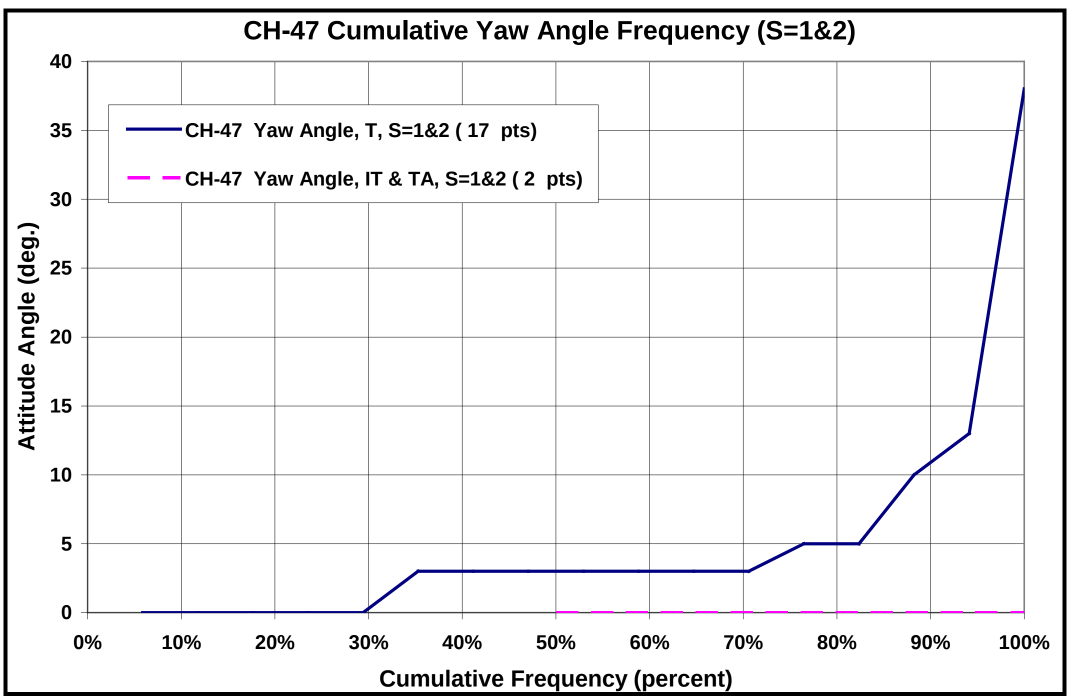

Figure D-34 – CH-47 Cumulative Yaw Angle Frequency (S=1&2)

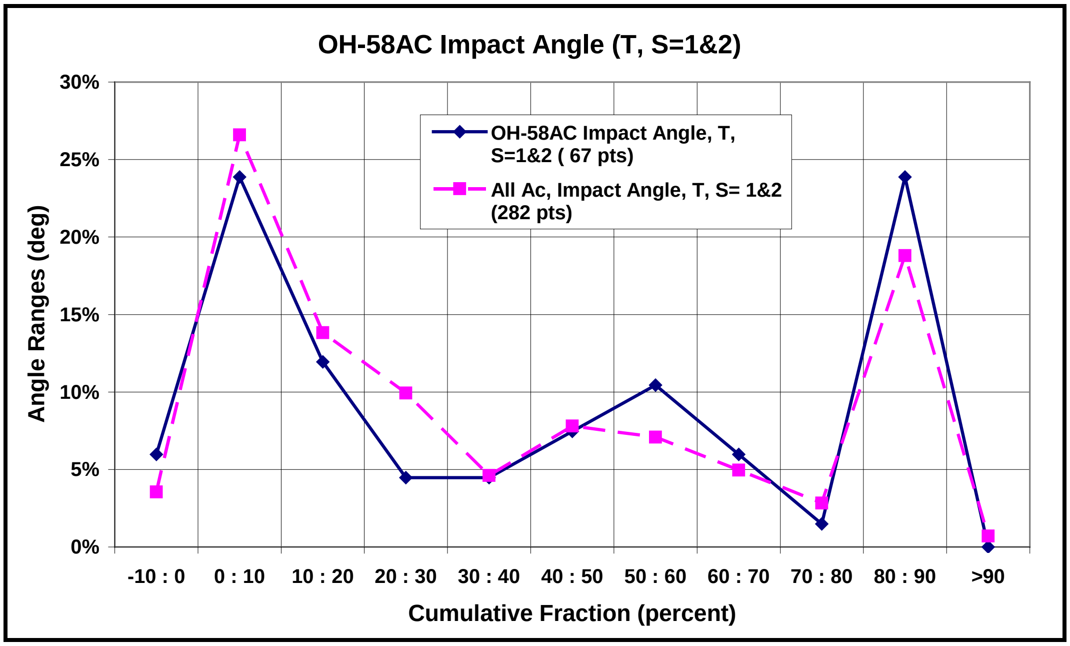

Figure D-35 – OH-58AC Impact Angle (T, S=1&2)

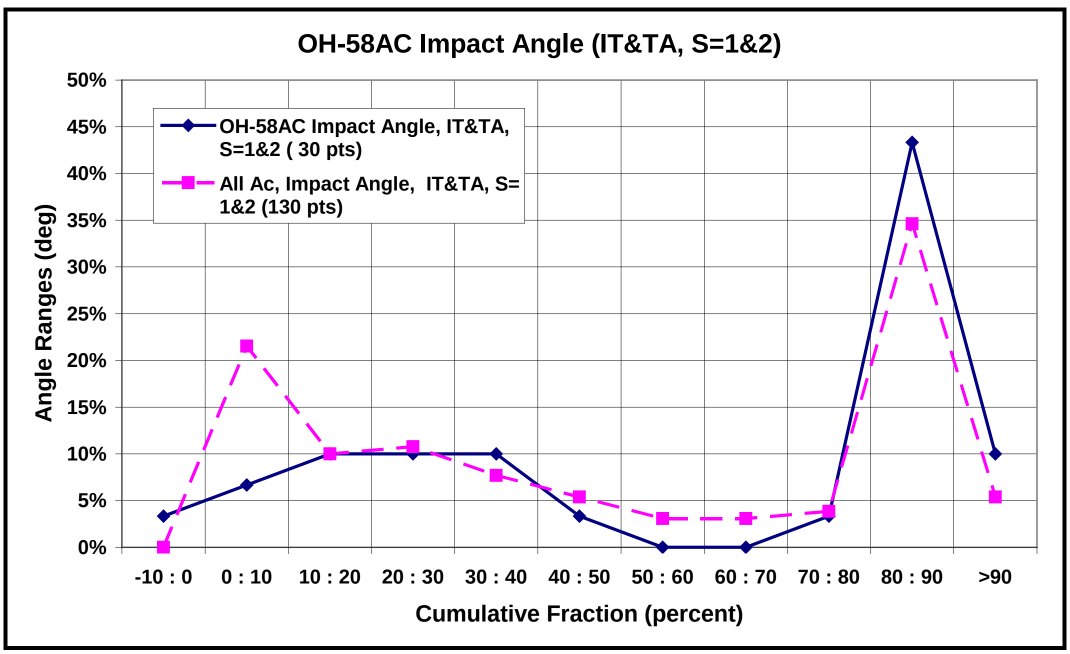

Figure D-36 – OH-58AC Impact Angle (IT&TA, S=1&2)

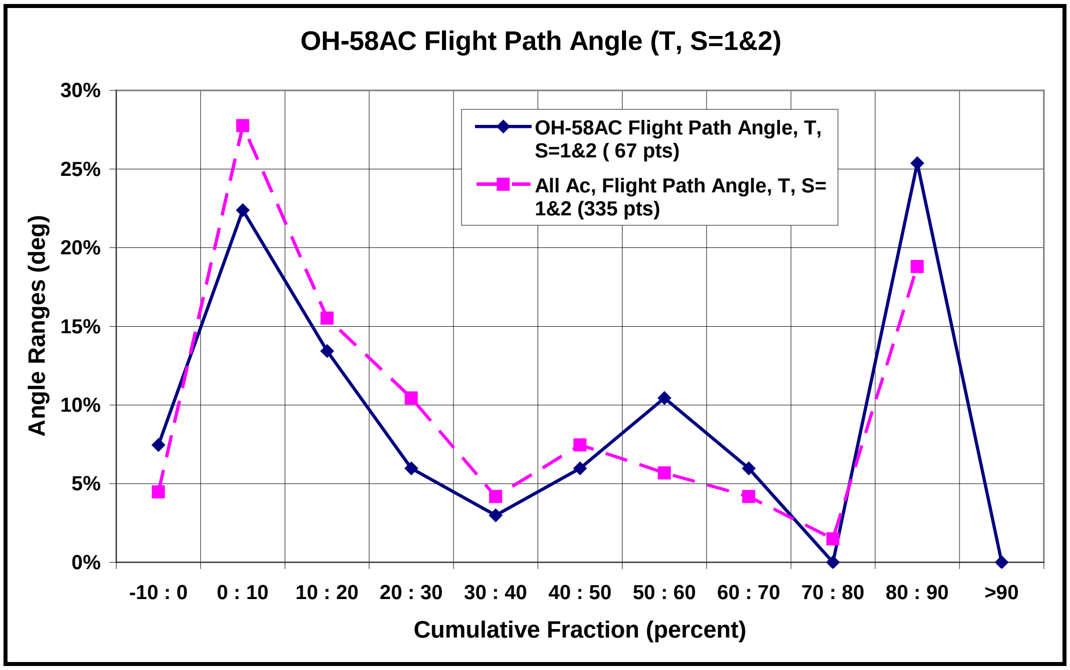

Figure D-37 – OH-58AC Flight Path Angle (T, S=1&2)

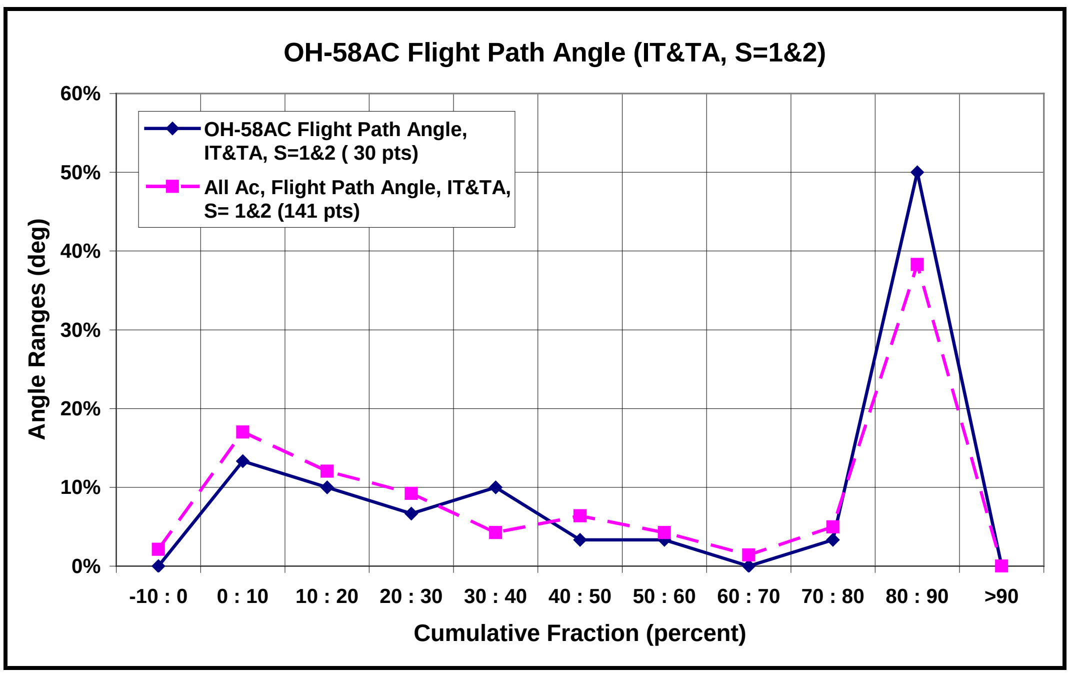

Figure D-38 – OH-58AC Flight Path Angle (IT&TA, S=1&2)

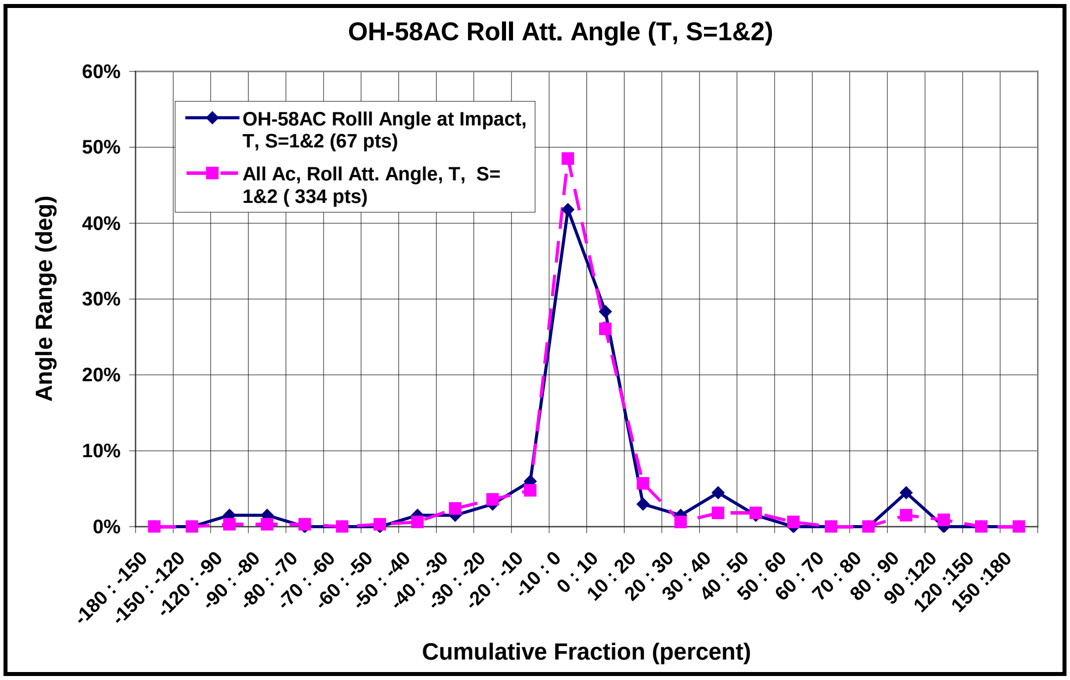

Figure D-39 – OH-58AC Roll Attitude Angle (T, S=1&2)

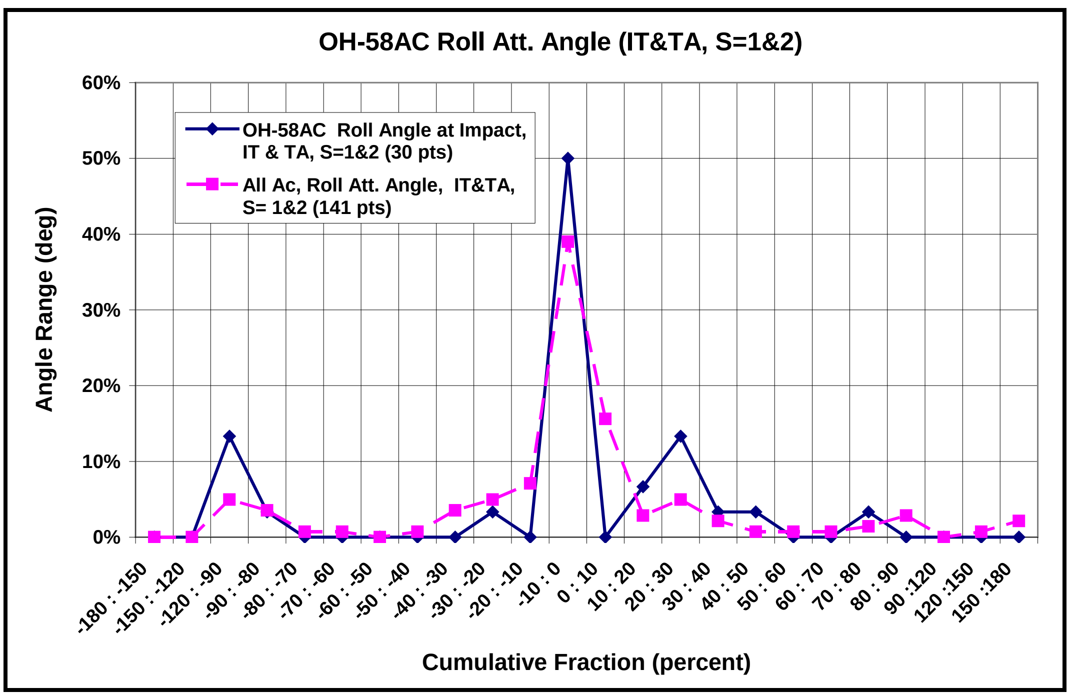

Figure D-40 – OH-58AC Roll Attitude Angle (IT&TA, S=1&2)

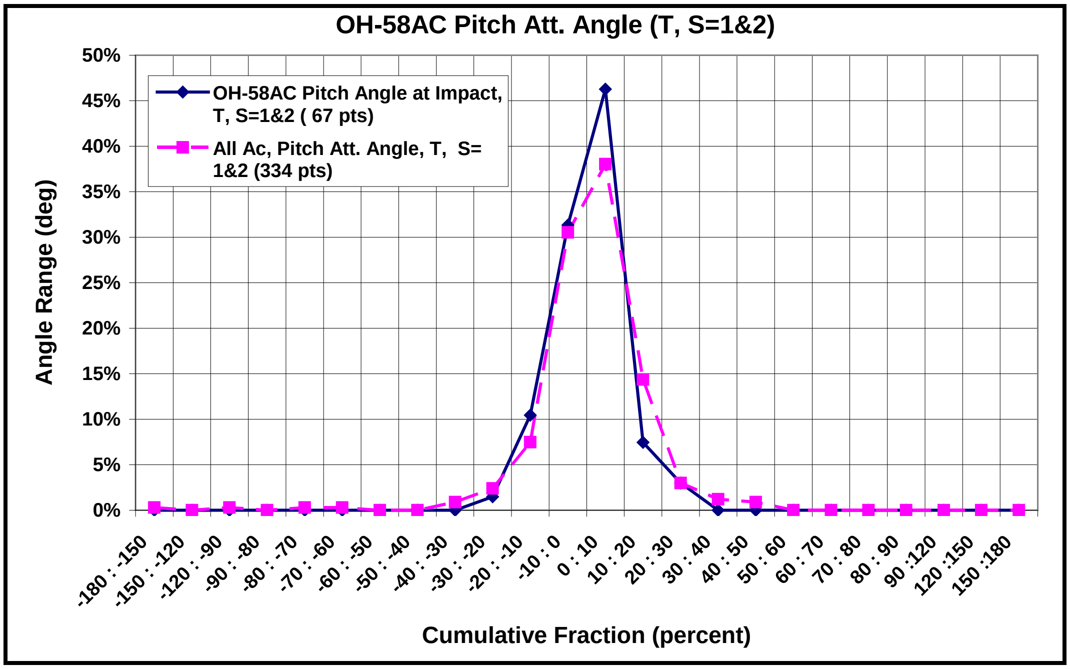

Figure D-41 – OH-58AC Pitch Attitude Angle (T, S=1&2)

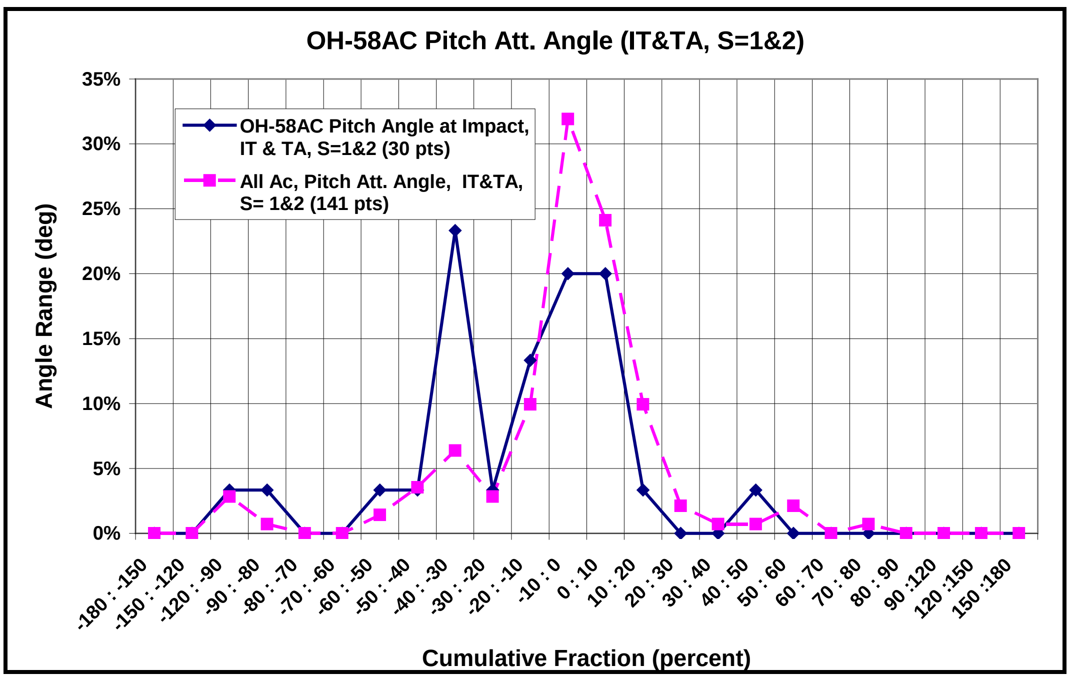

Figure D-42 – OH-58AC Pitch Attitude Angle (IT&TA, S=1&2)

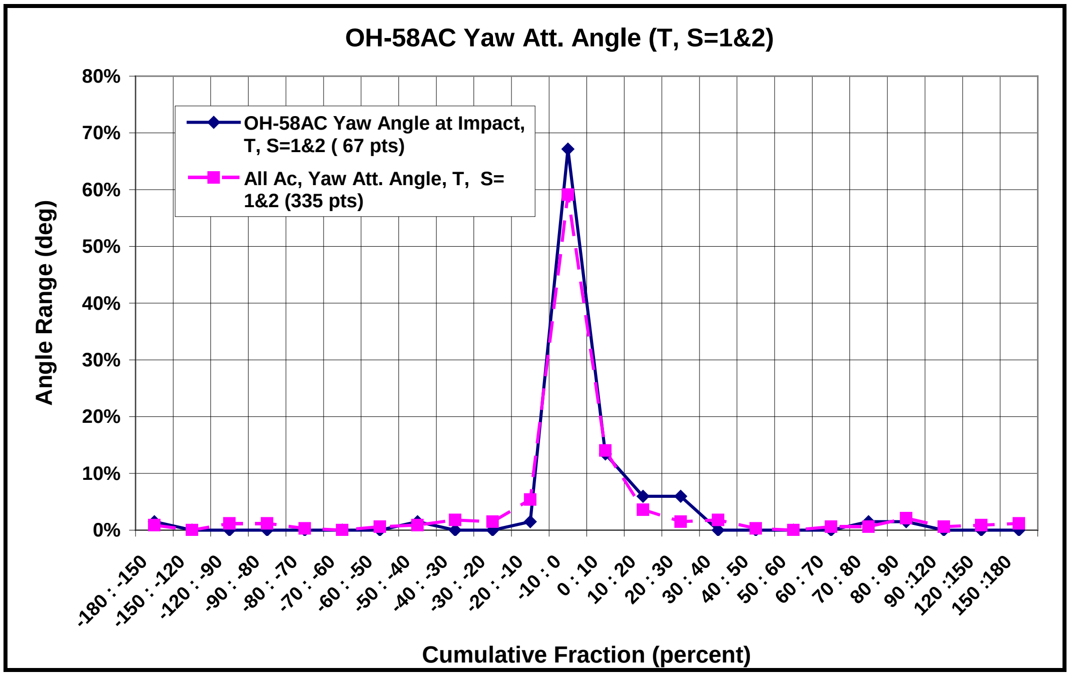

Figure D-43 – OH-58AC Yaw Attitude Angle (T, S=1&2)

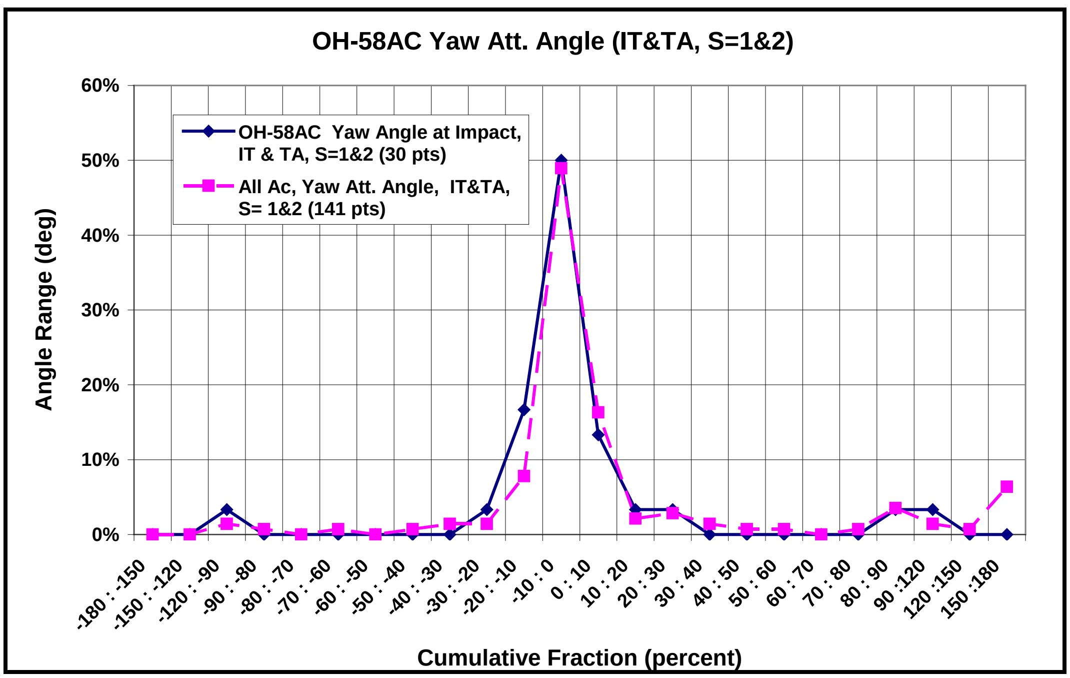

Figure D-44 – OH-58AC Yaw Attitude Angle (IT&TA, S=1&2)

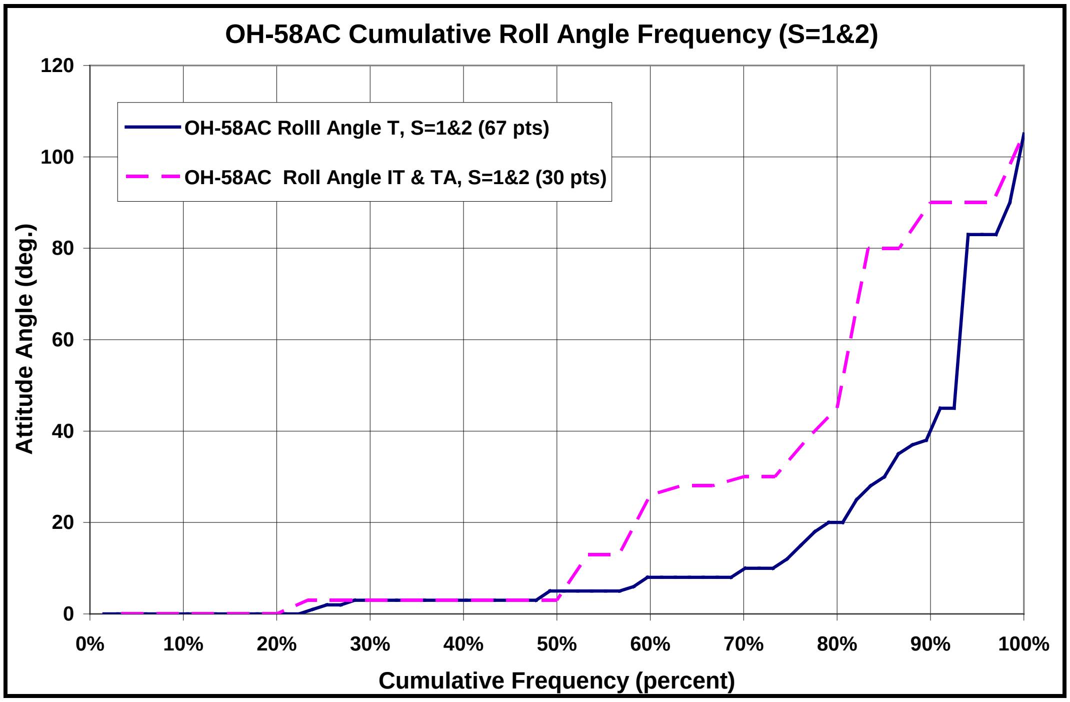

Figure D-45 – OH-58AC Cumulative Roll Angle Frequency (S=1&2)

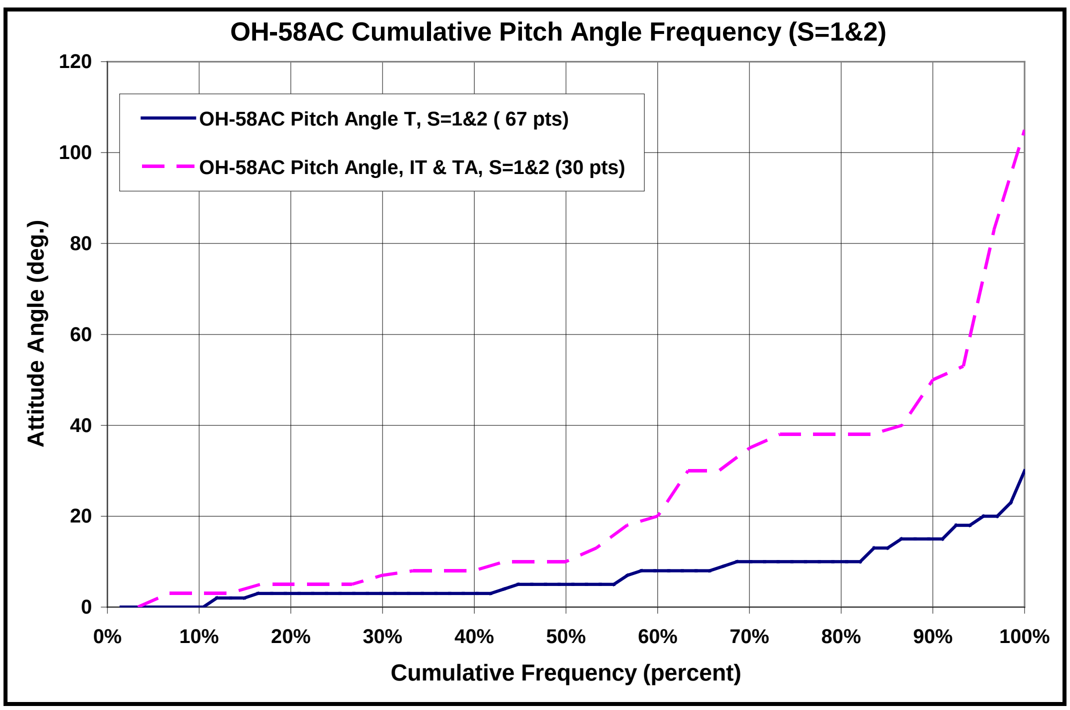

Figure D-46 – OH-58AC Cumulative Pitch Angle Frequency (S=1&2)

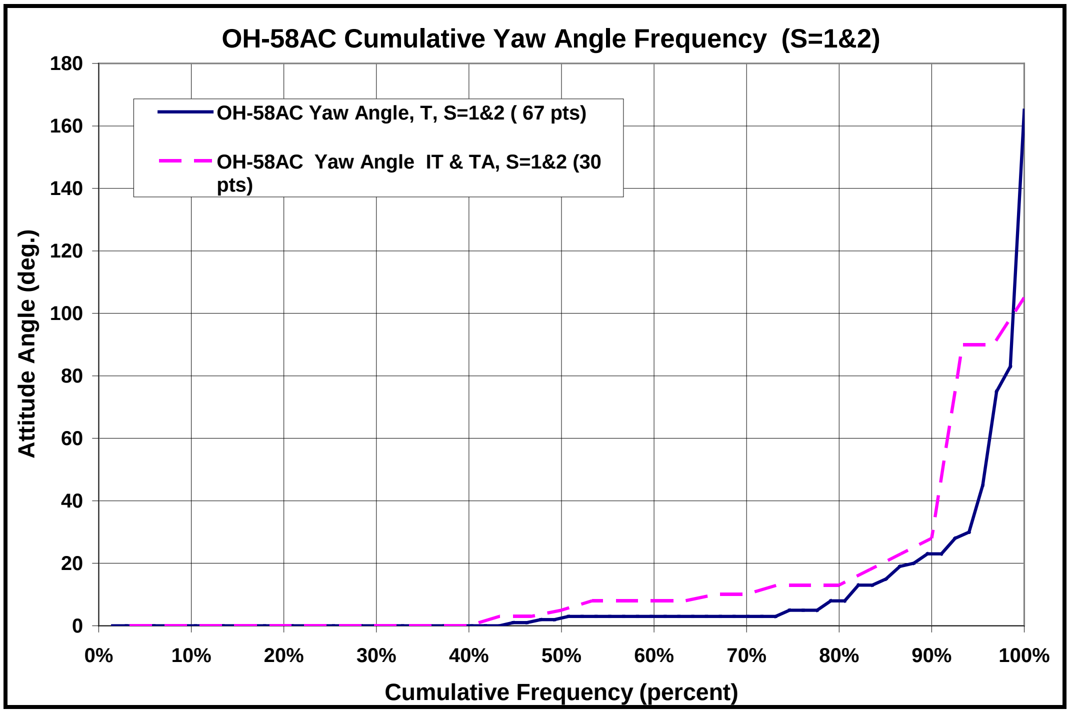

Figure D-47 – OH-58AC Cumulative Yaw Angle Frequency (S=1&2)

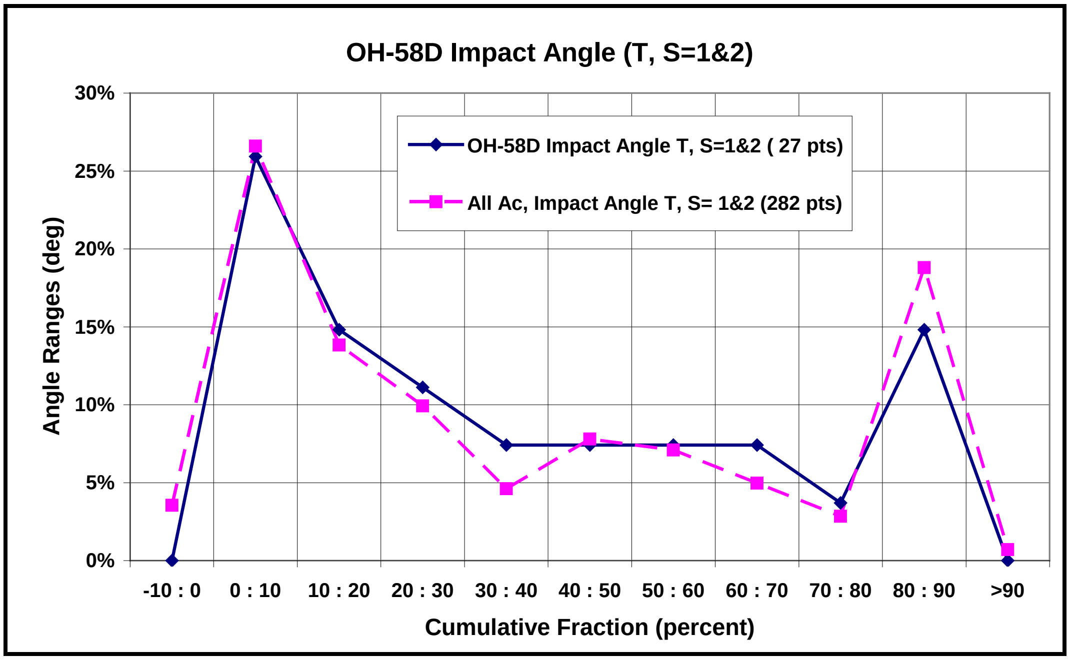

Figure D-48 – OH-58D Impact Angle (T, S=1&2)

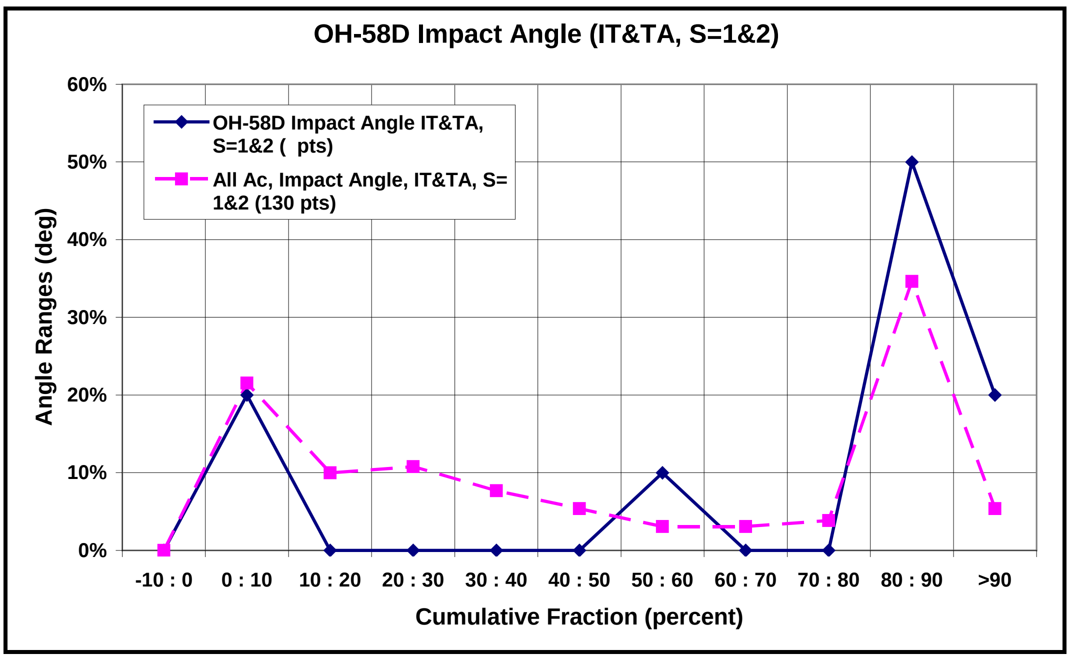

Figure D-49 – OH-58D Impact Angle (IT&TA, S=1&2)

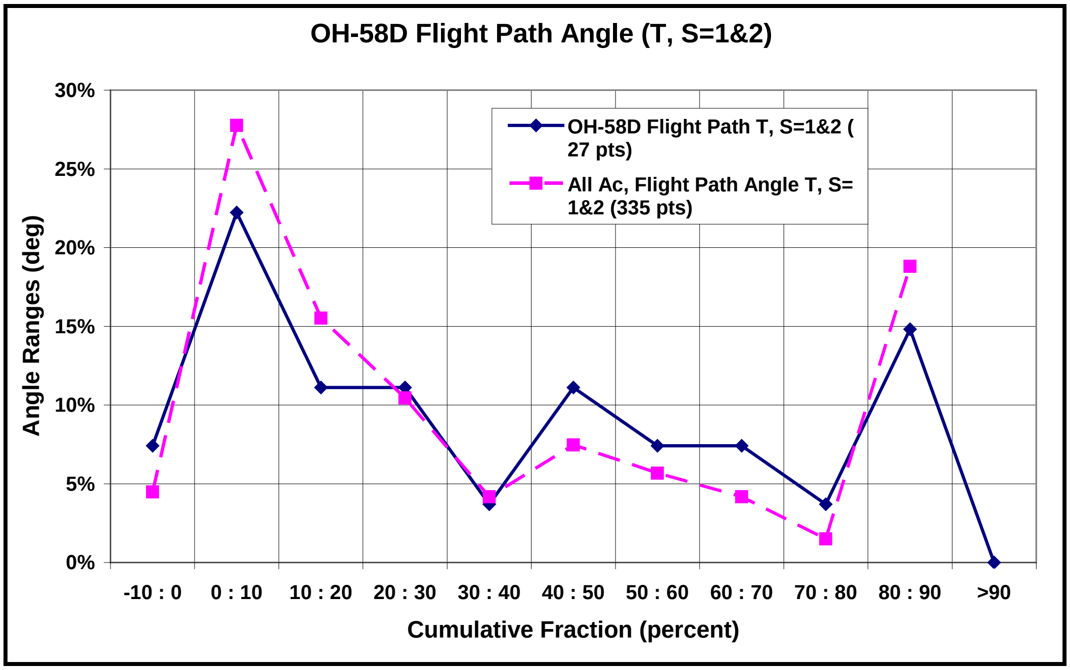

Figure D-50 – OH-58D Flight Path Angle (T, S=1&2)

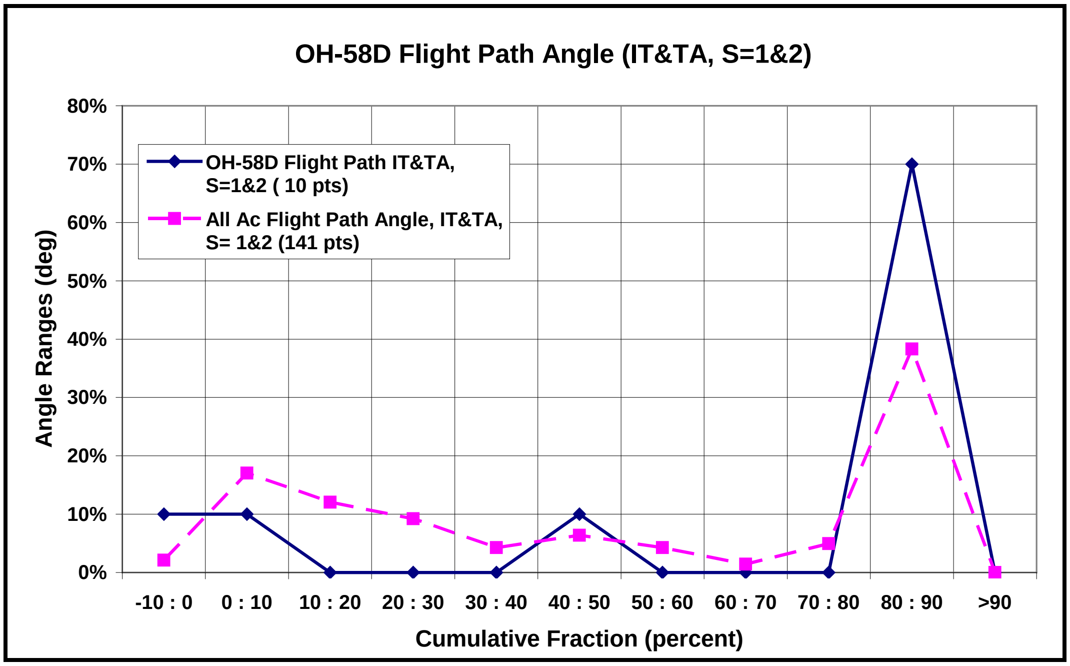

Figure D-51 – OH-58D Flight Path Angle (IT&TA, S=1&2)

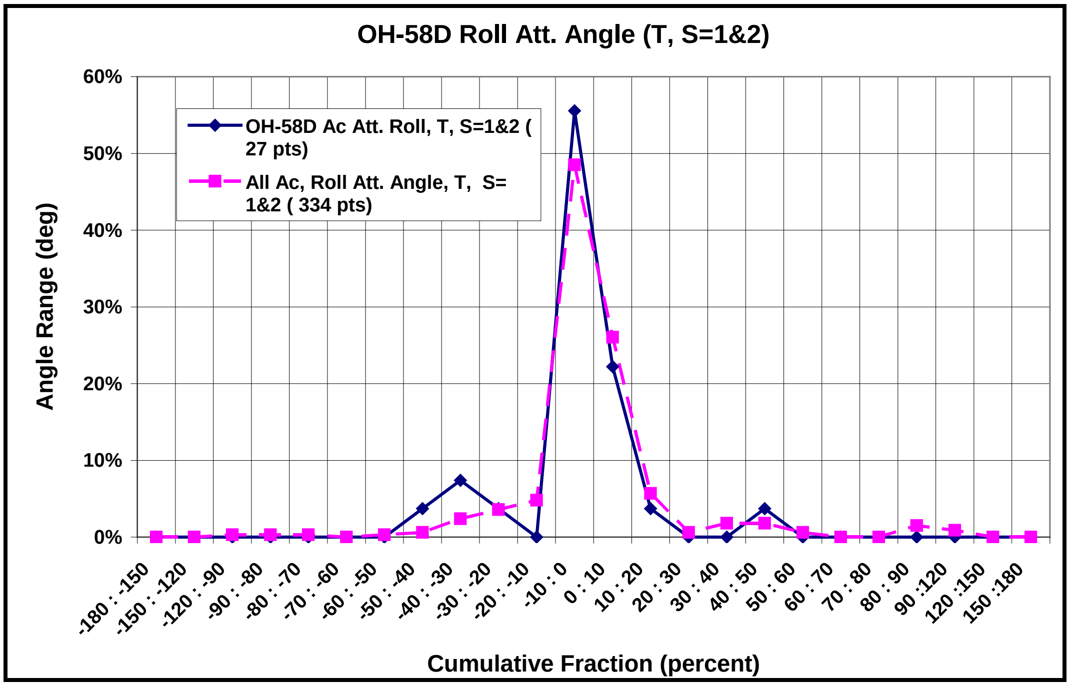

Figure D-52 – OH-58D Roll Attitude Angle (T, S=1&2)

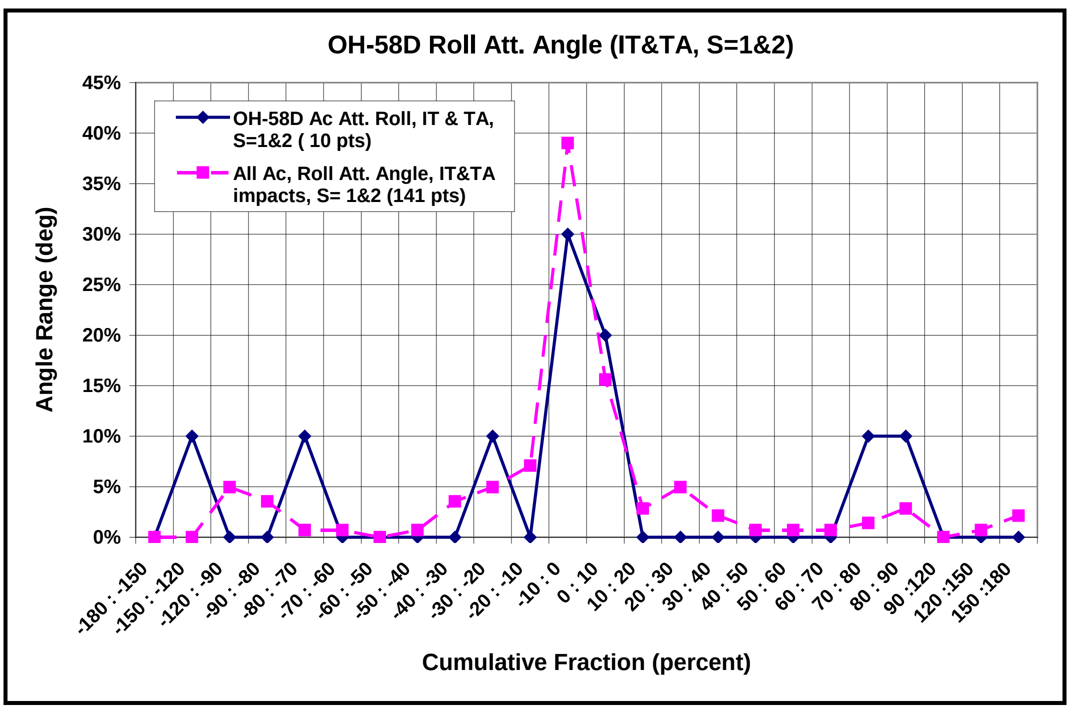

Figure D-53 – OH-58D Roll Attitude Angle (IT&TA, S=1&2)

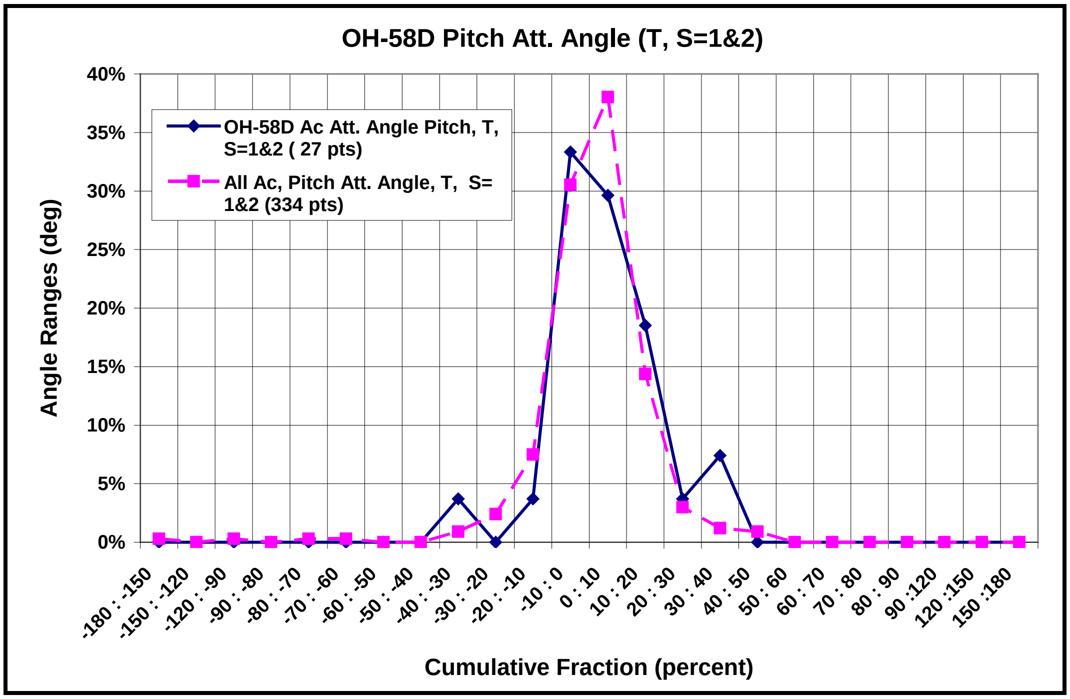

Figure D-54 – OH-58D Pitch Attitude Angle (T, S=1&2)

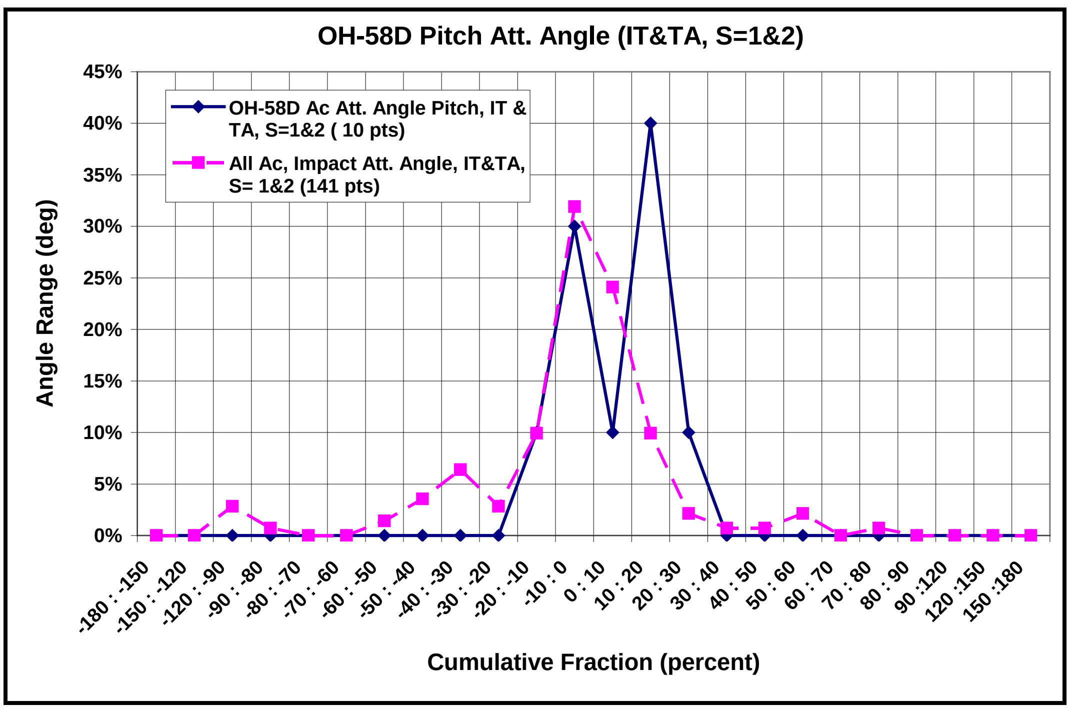

Figure D-55 – OH-58D Pitch Attitude Angle (IT&TA, S=1&2)

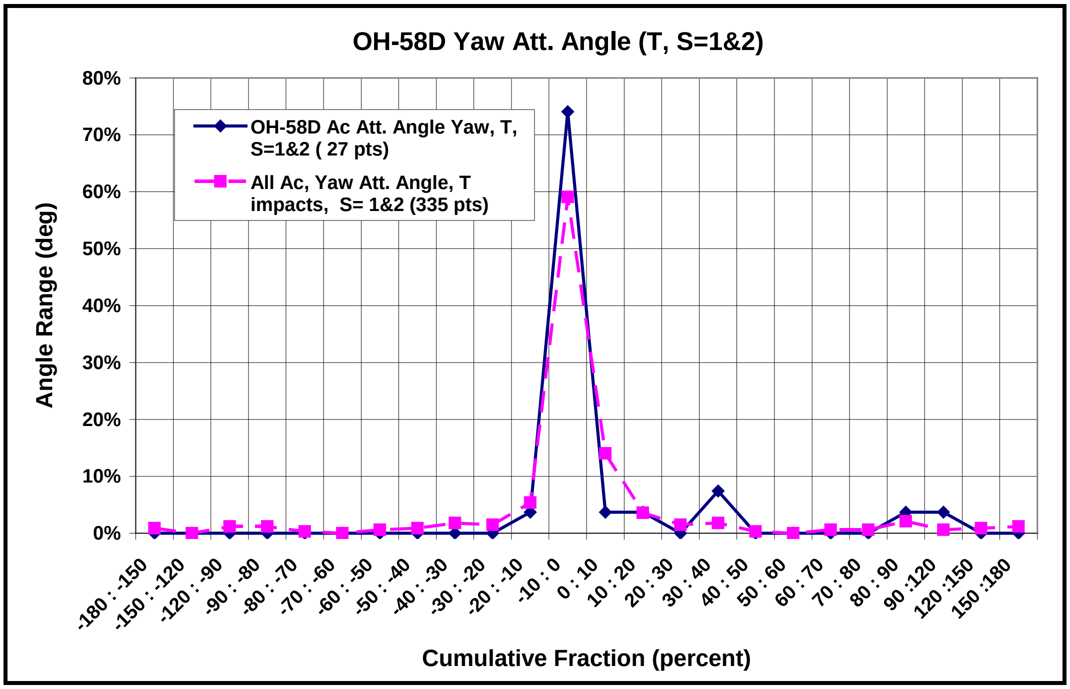

Figure D-56 – OH-58D Yaw Attitude Angle (T, S=1&2)

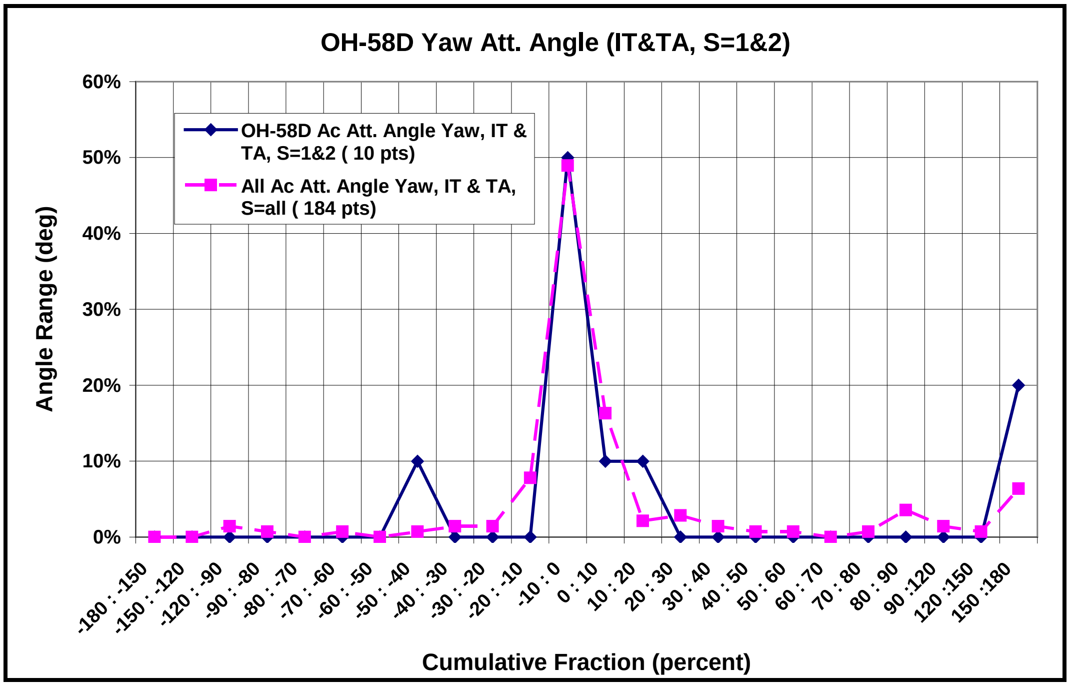

Figure D-57 – OH-58D Yaw Attitude Angle (IT&TA, S=1&2)

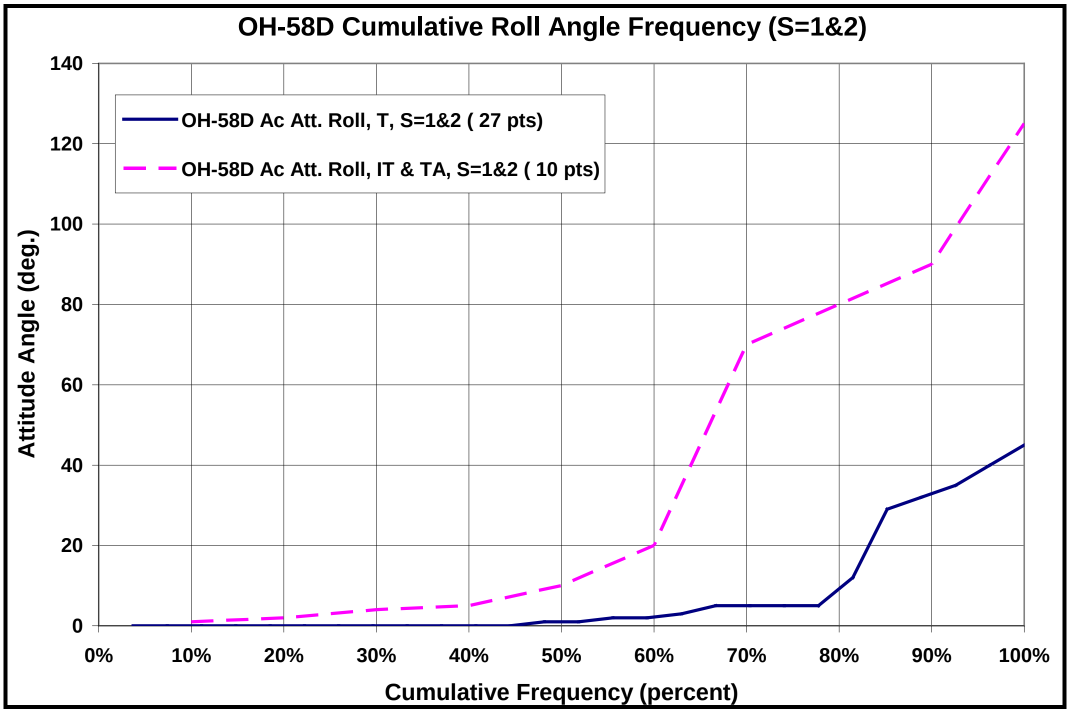

Figure D-58 – OH-58D Cumulative Roll Angle Frequency (S=1&2)

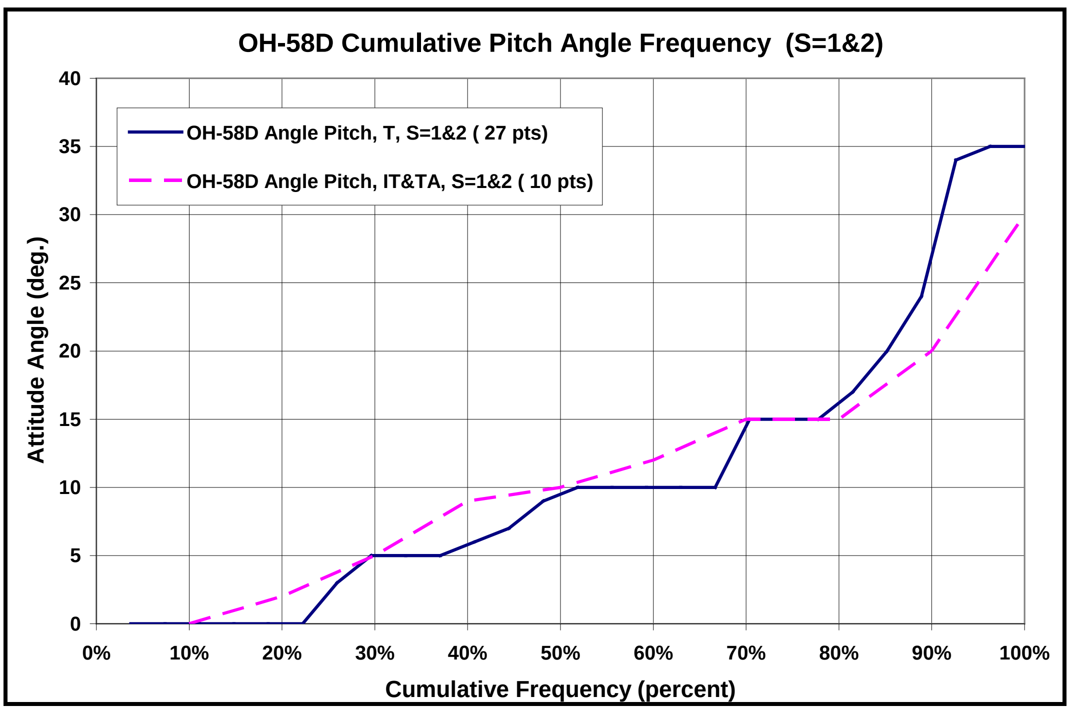

Figure D-59 – OH-58D Cumulative Pitch Angle Frequency (S=1&2)

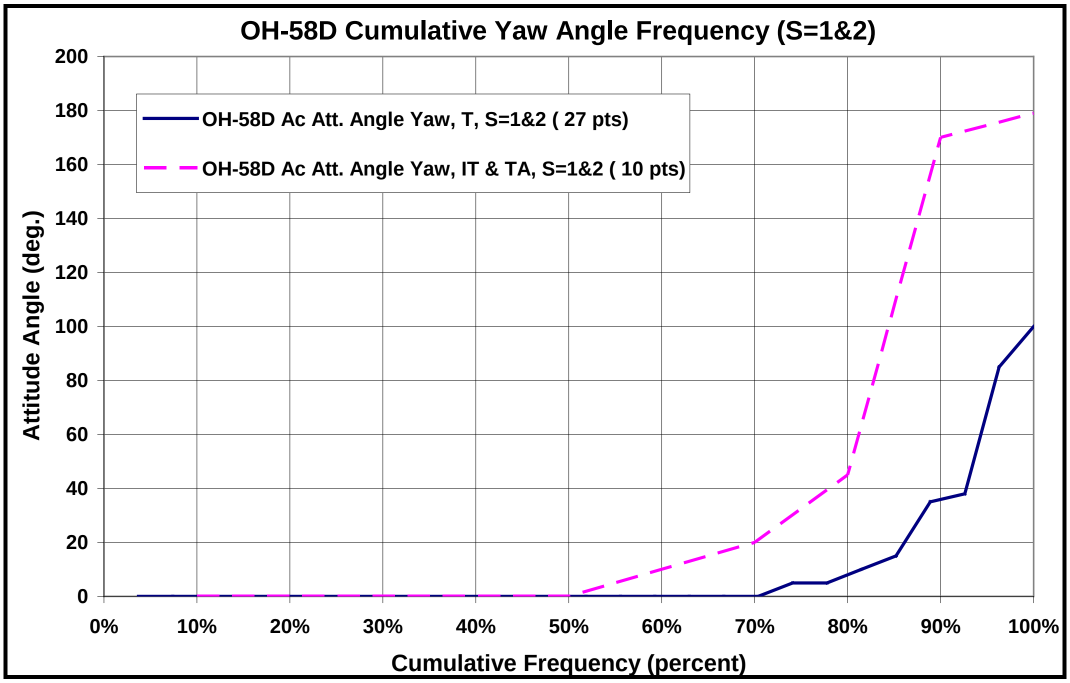

Figure D-60 – OH-58D Cumulative Yaw Angle Frequency (S=1&2)

Note: There were too few IT&TA mishaps to plot the angle data for the OH-6.

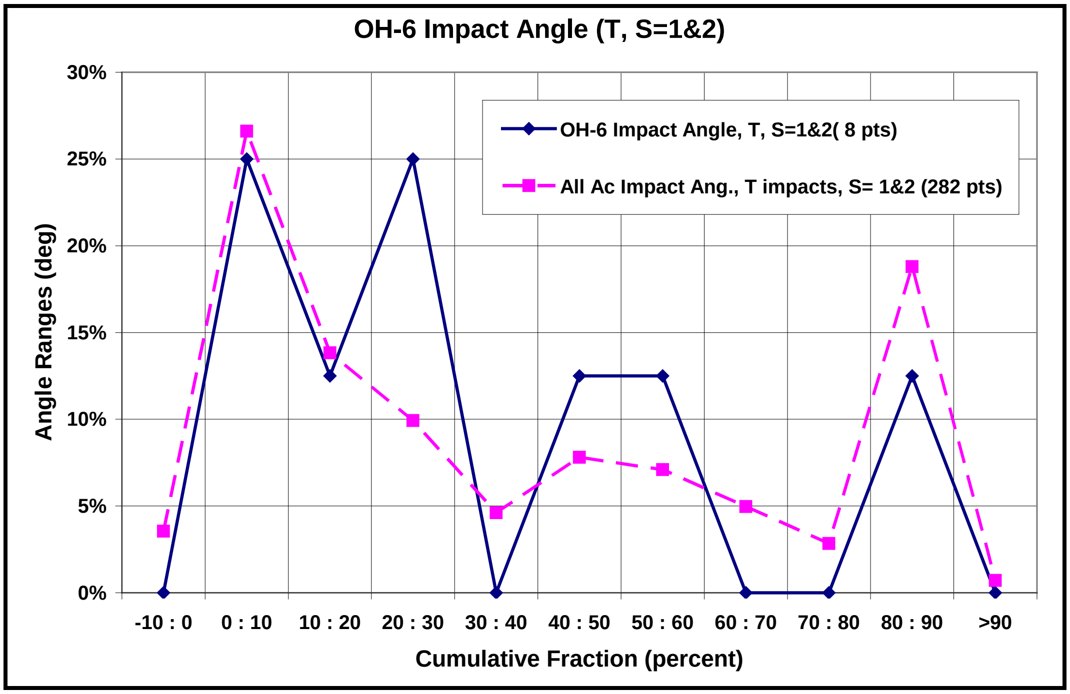

Figure D-61 – OH-6 Impact Angle (T, S=1&2)

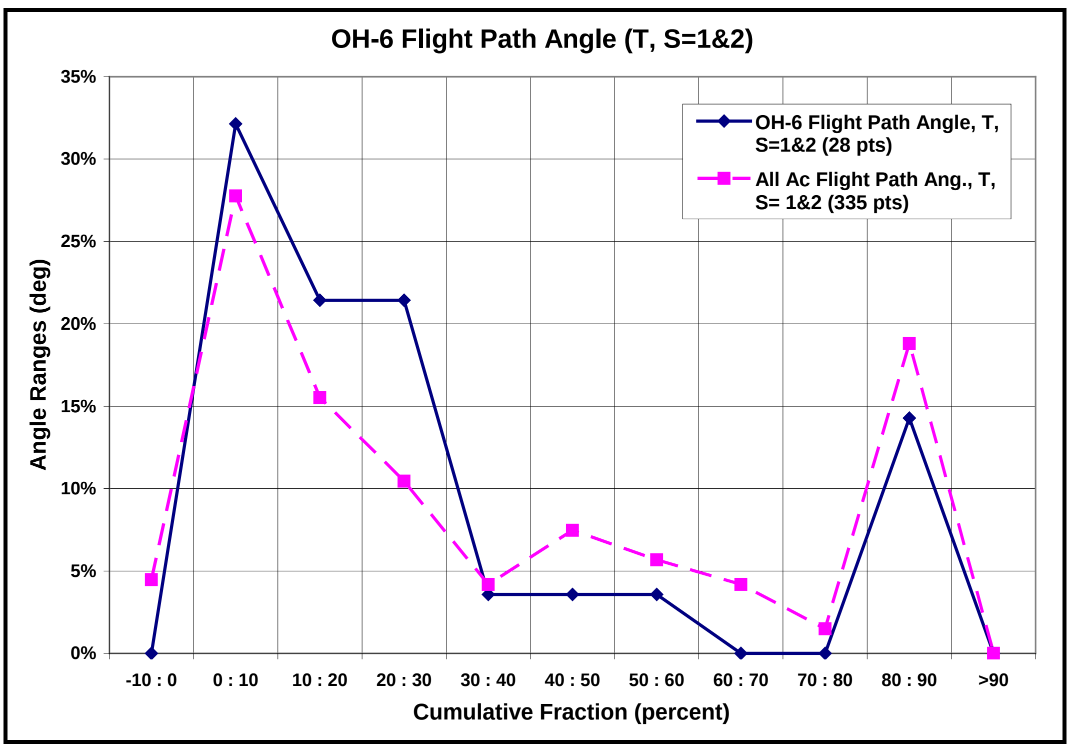

Figure D-62 – OH-6 Flight Path Angle (T, S=1&2)

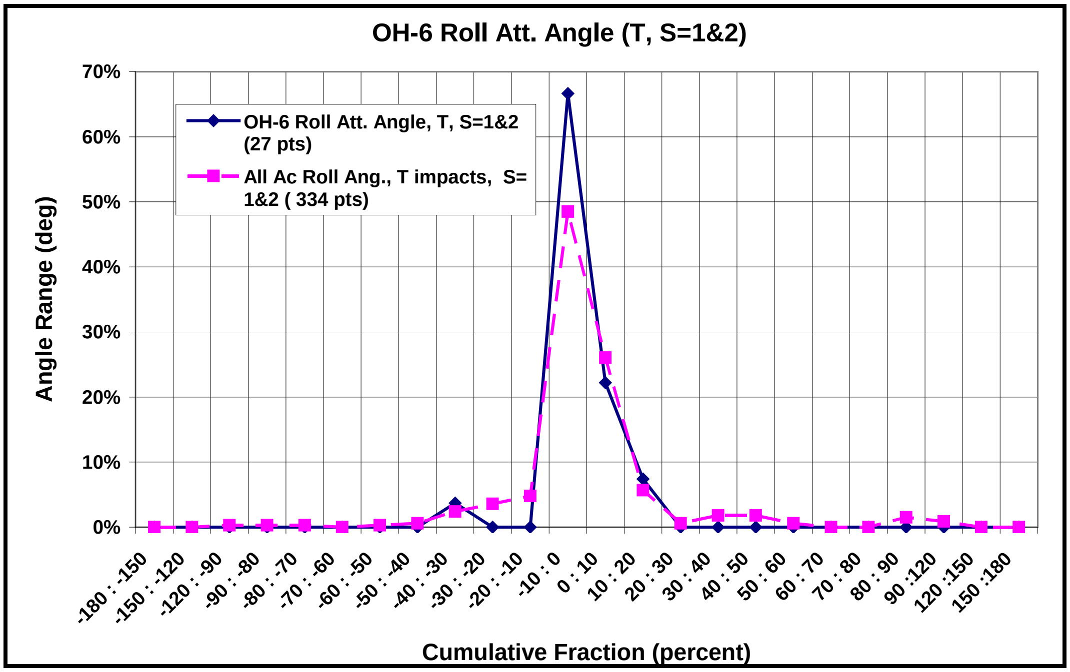

Figure D-63 – OH-6 Roll Attitude Angle (T, S=1&2)

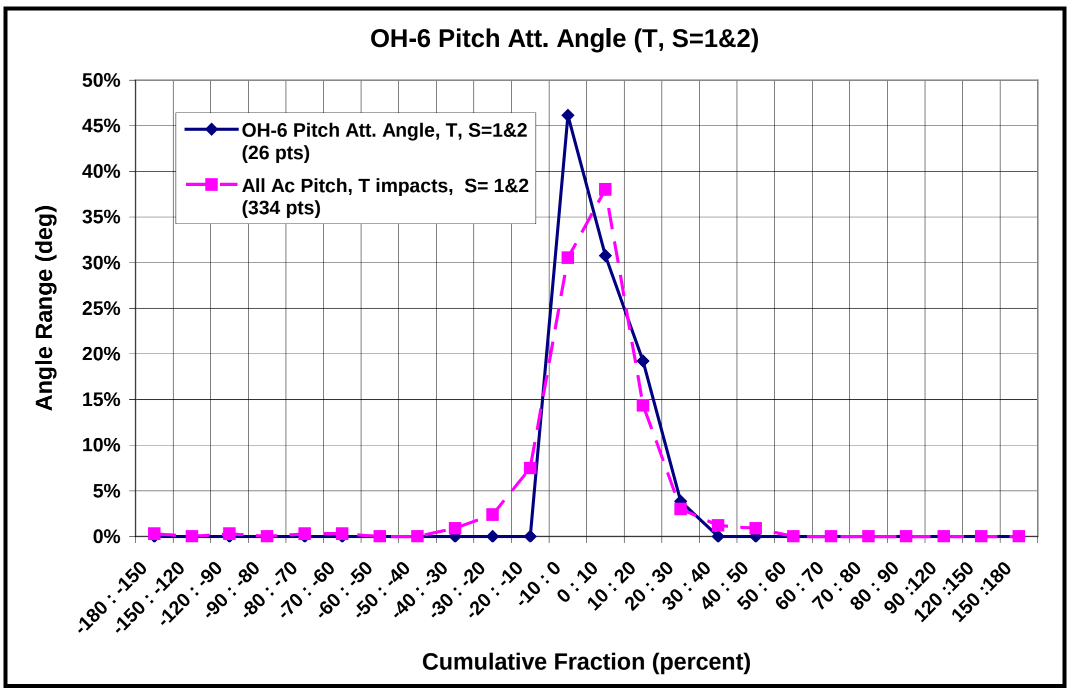

Figure D-64 – OH-6 Pitch Attitude Angle (T, S=1&2)

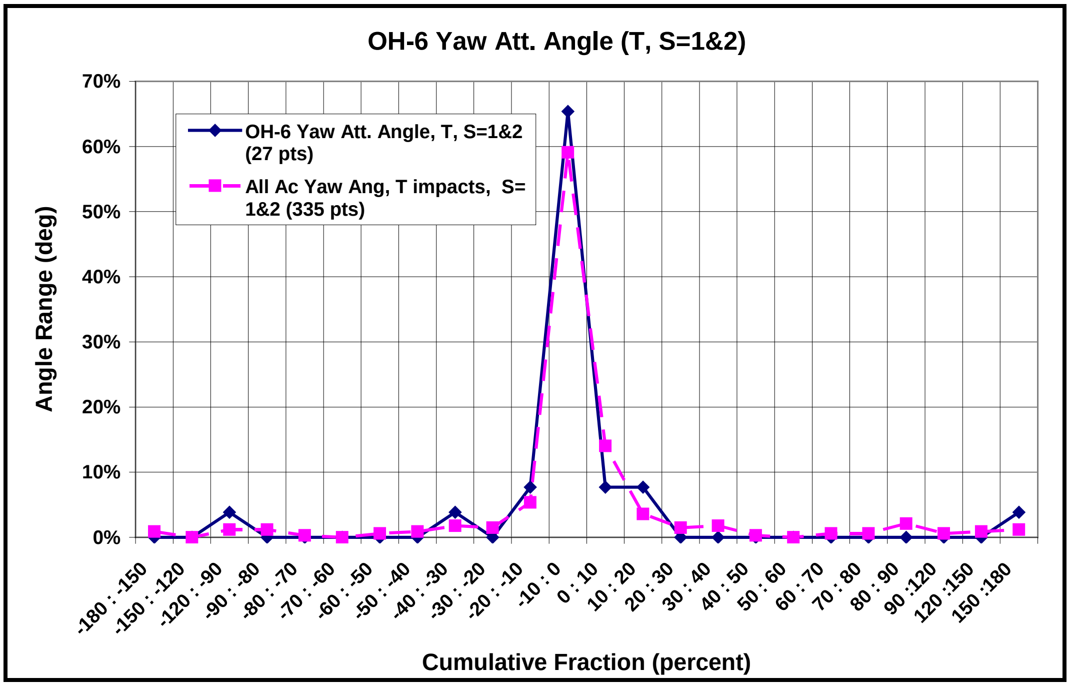

Figure D-65 – OH-6 Yaw Attitude Angle (T, S=1&2)

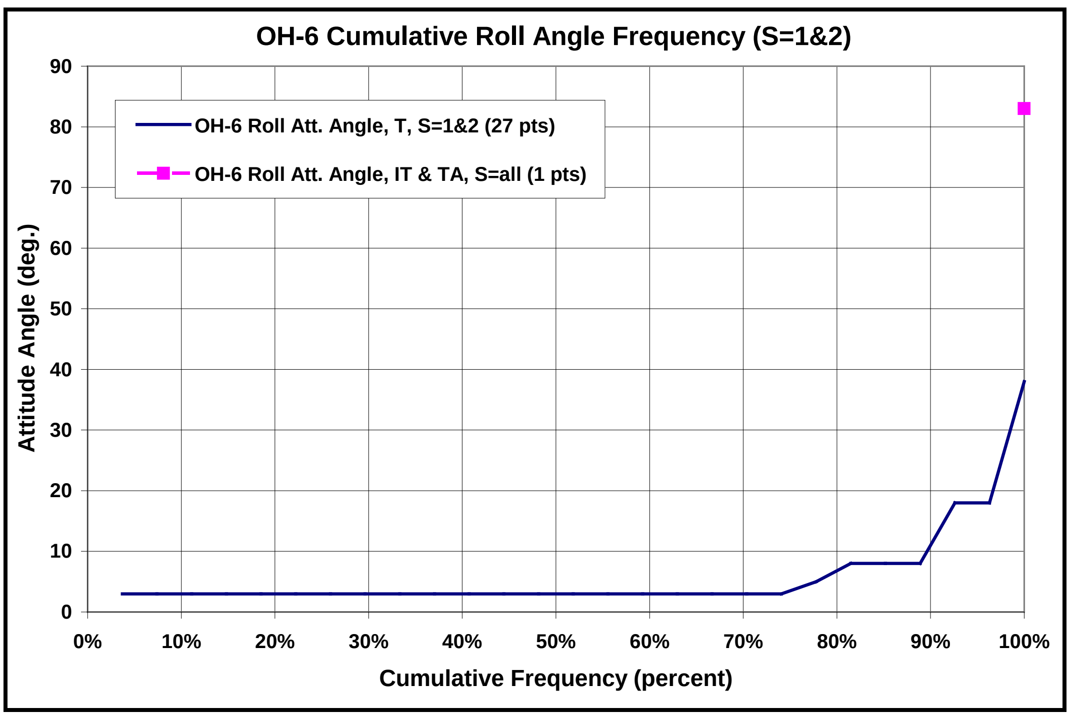

Figure D-66– OH-6 Cumulative Roll Angle Frequency (S=1&2)

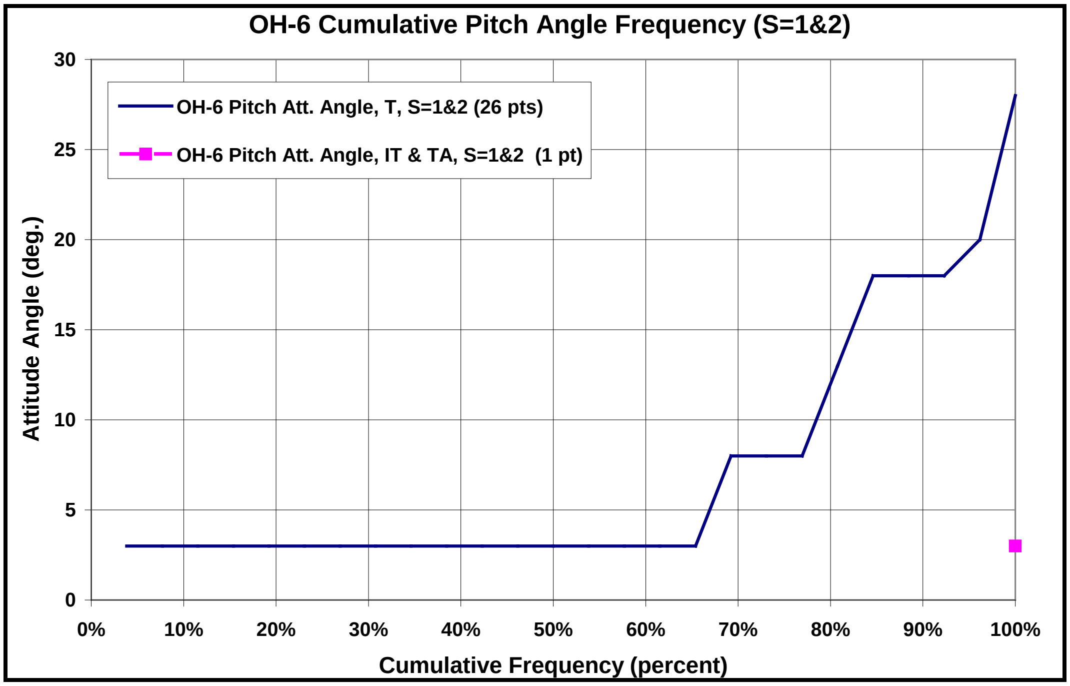

Figure D-67 – OH-6 Cumulative Pitch Angle Frequency (S=1&2)

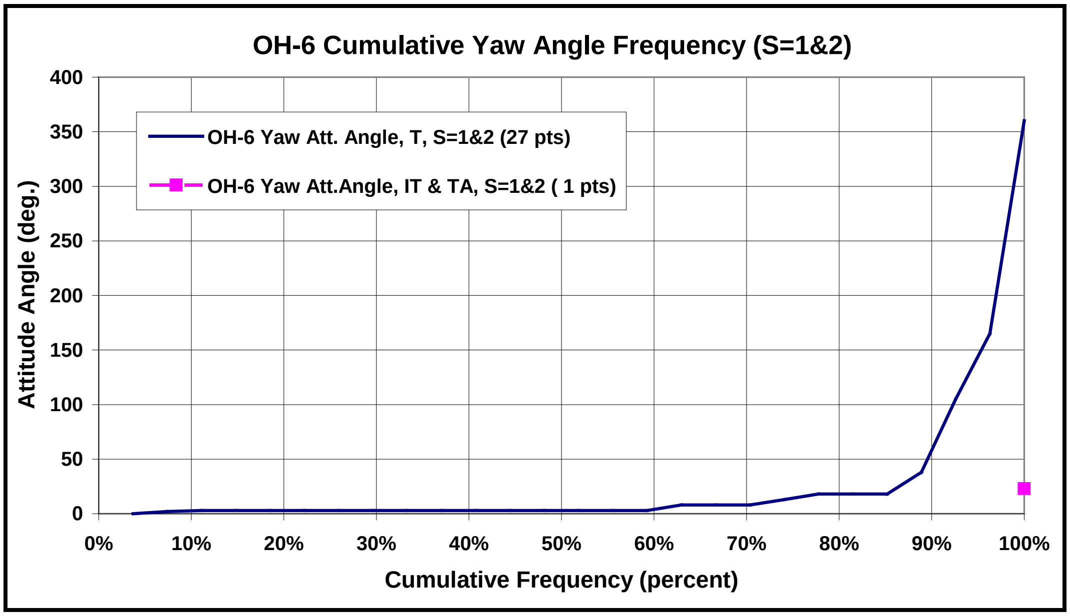

Figure D-68 – OH-6 Cumulative Yaw Angle Frequency (S=1&2)

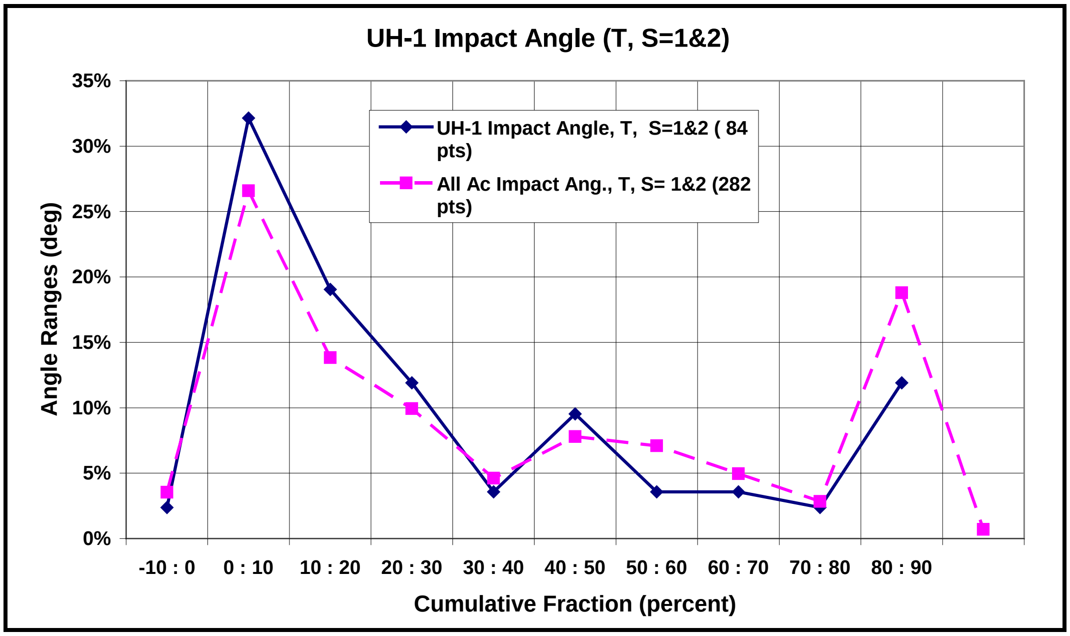

Figure D-69 – UH-1 Impact Angle (T, S=1&2)

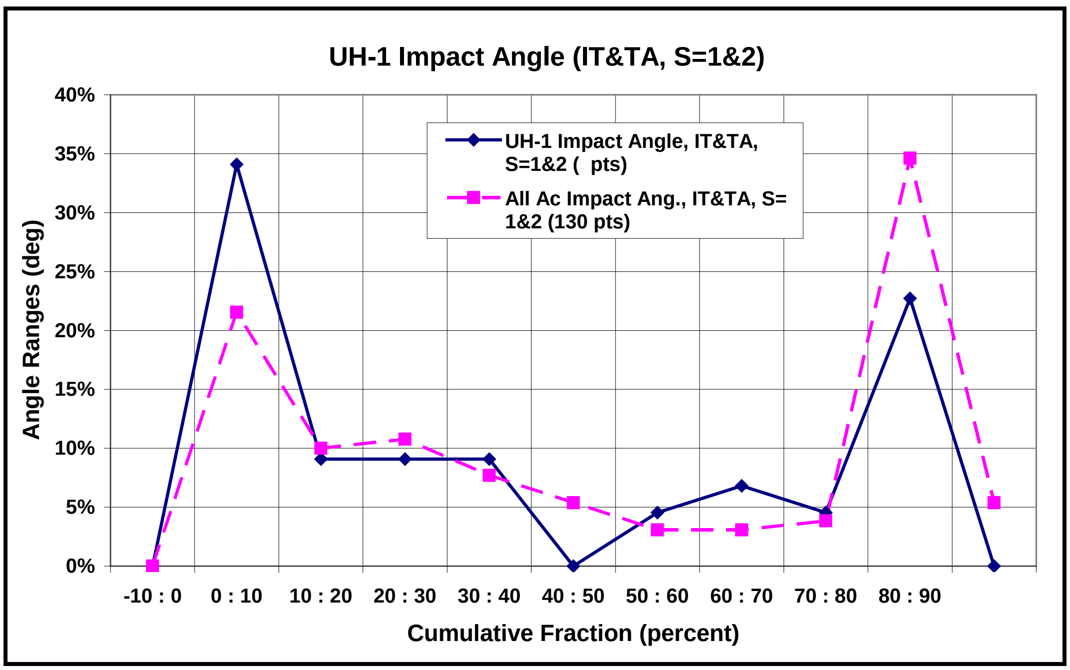

Figure D-70 – UH-1 Impact Angle (IT&TA, S=1&2)

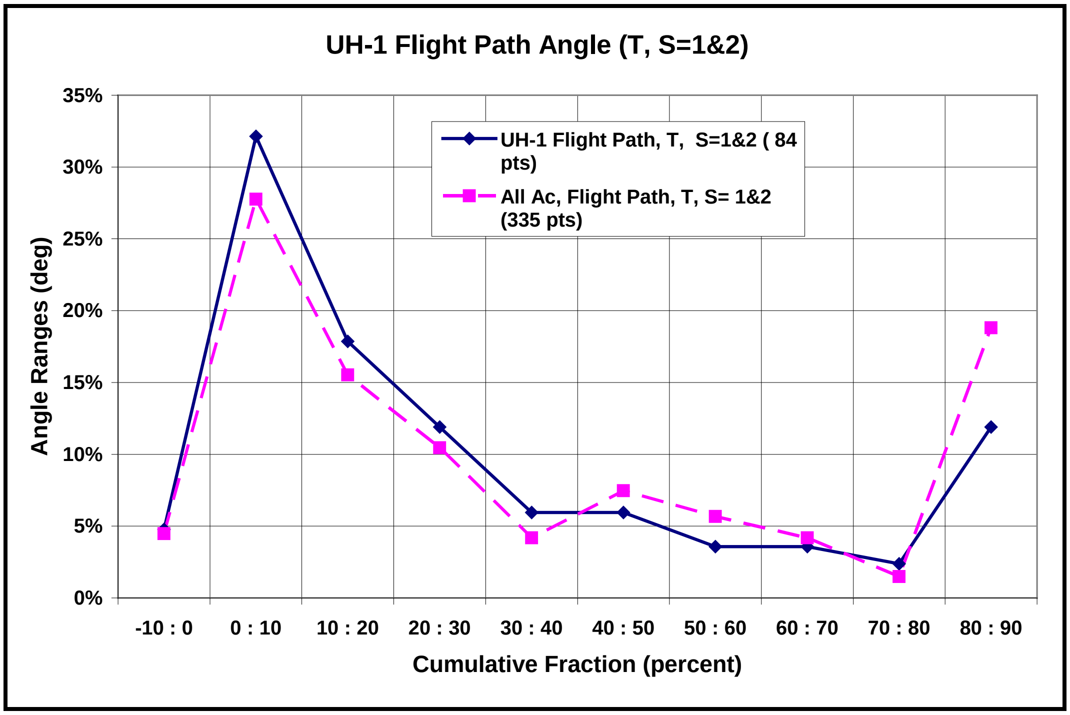

Figure D-71 – UH-1 Flight Path Angle (T, S=1&2)

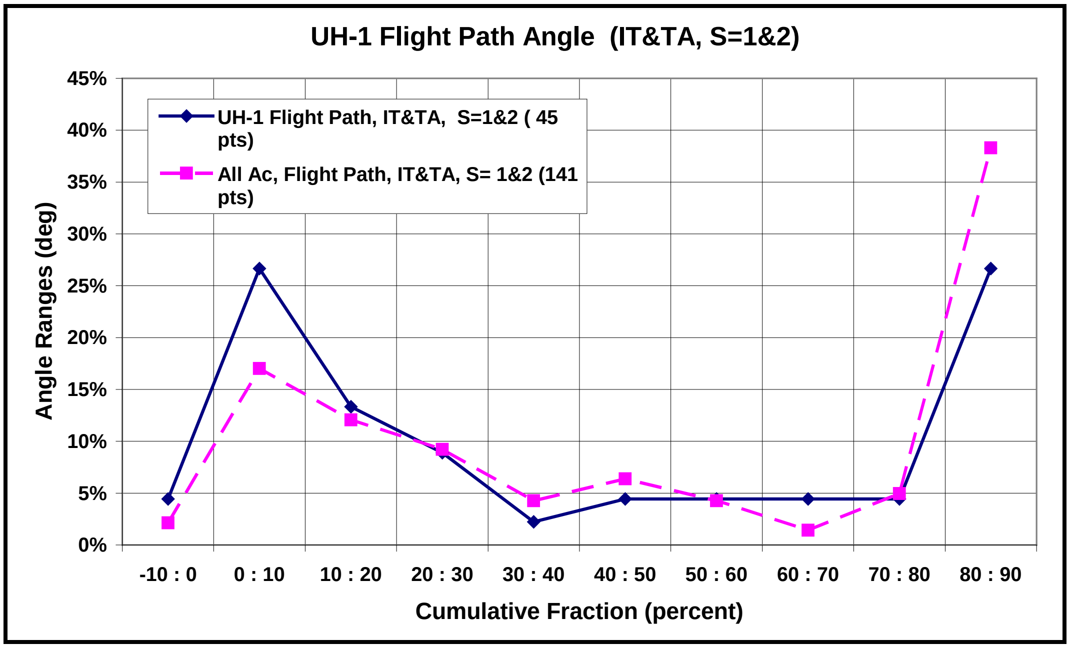

Figure D-72 – UH-1 Flight Path Angle (IT&TA, S=1&2)

Distribution: Unlimited

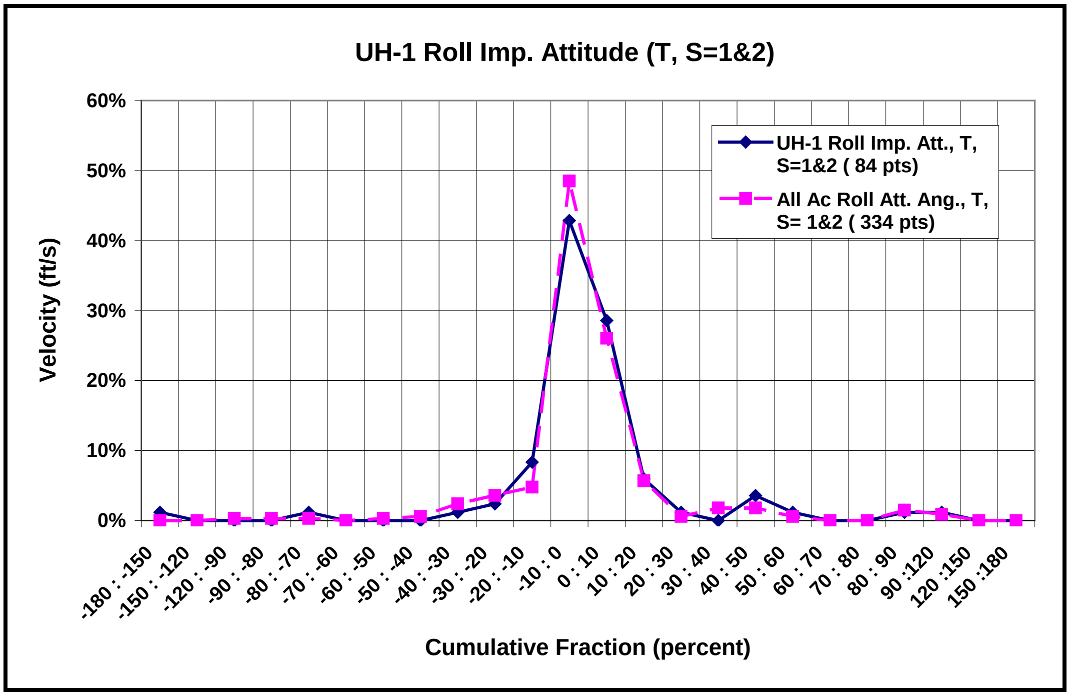

Figure D-73 – UH-1 Roll Attitude Angle (T, S=1&2)

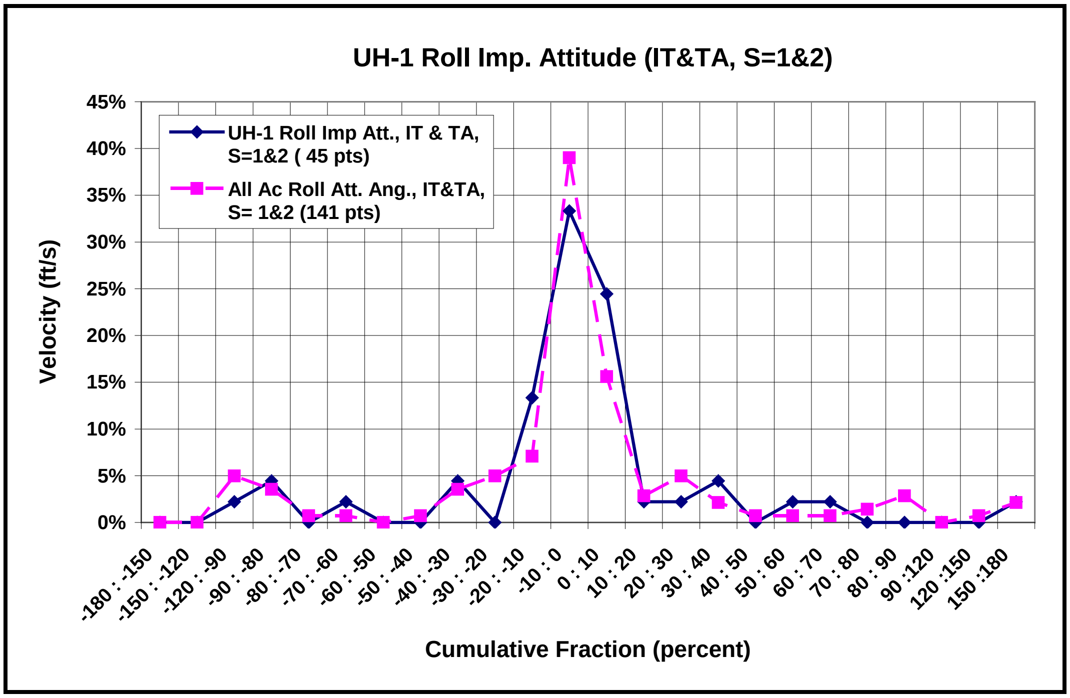

Figure D-74 – UH-1 Roll Attitude Angle (IT&TA, S=1&2)

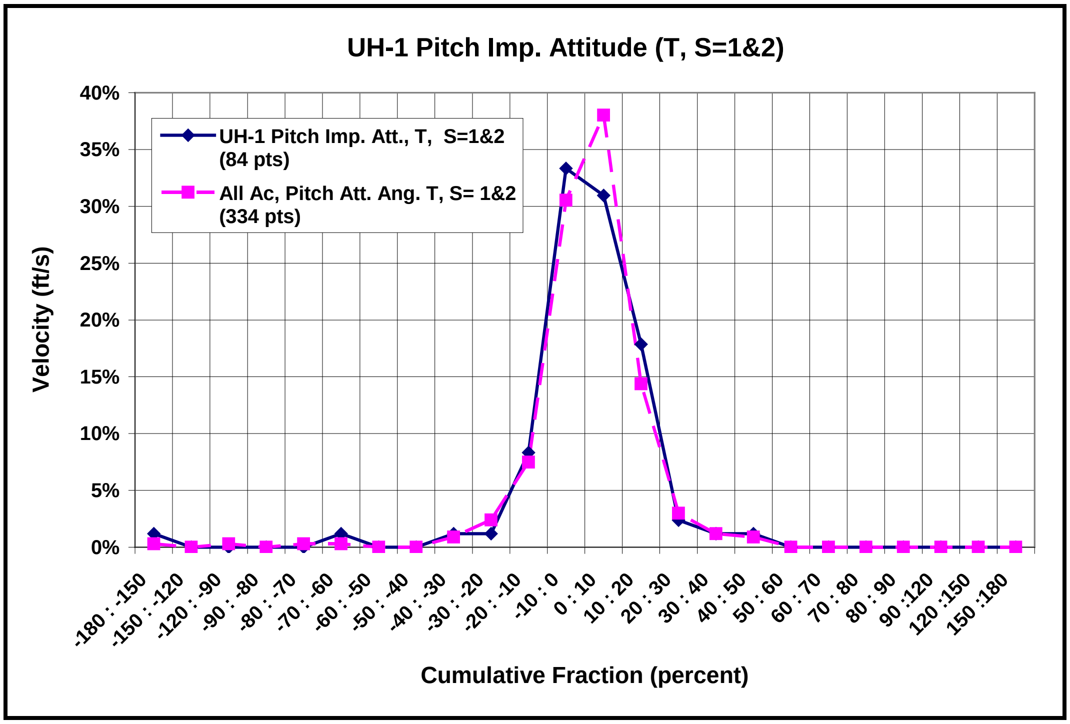

Figure D-75 – UH-1 Pitch Attitude Angle (T, S=1&2)

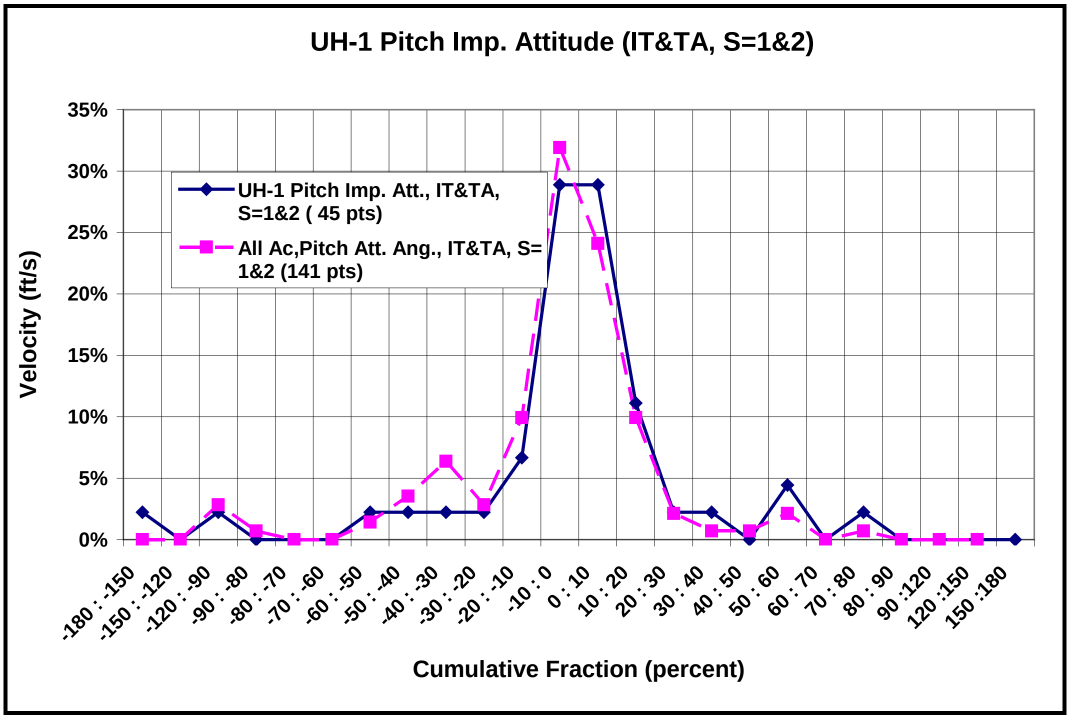

Figure D-76 – UH-1 Pitch Attitude Angle (IT&TA, S=1&2)

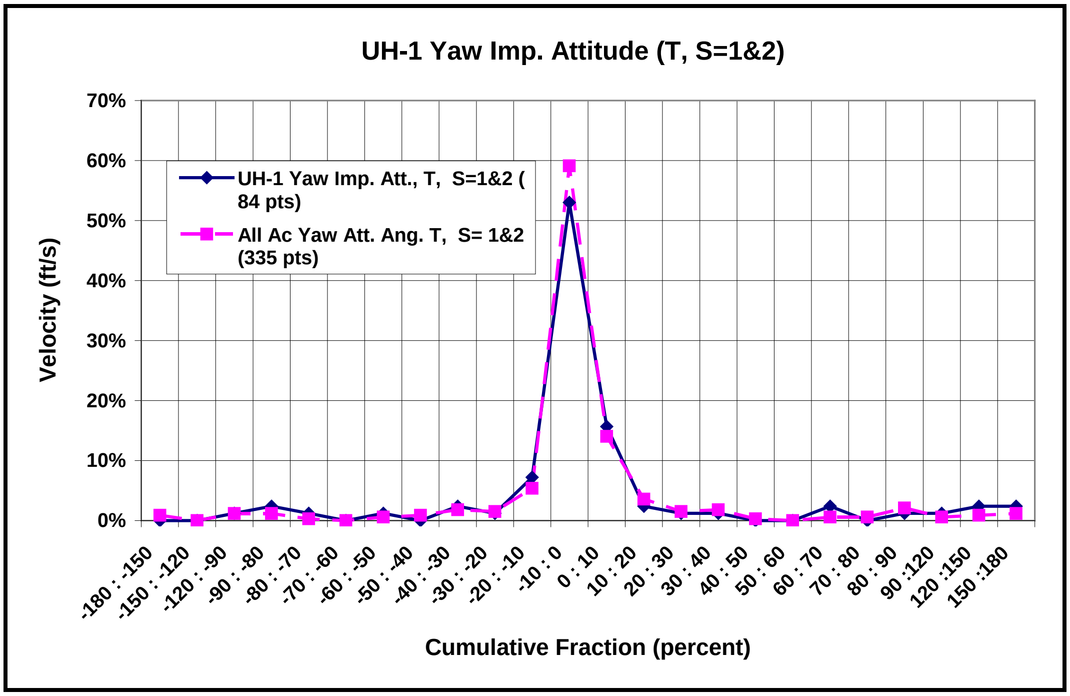

Figure D-77 – UH-1 Yaw Attitude Angle (T, S=1&2)

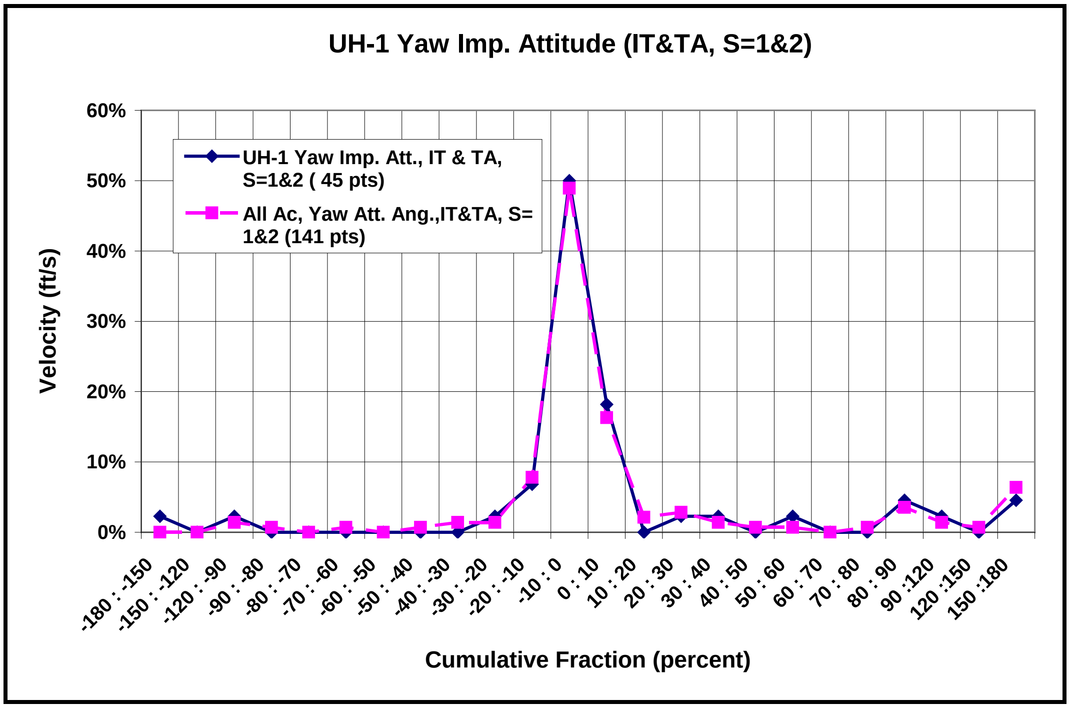

Figure D-78 – UH-1 Yaw Attitude Angle (IT&TA, S=1&2)

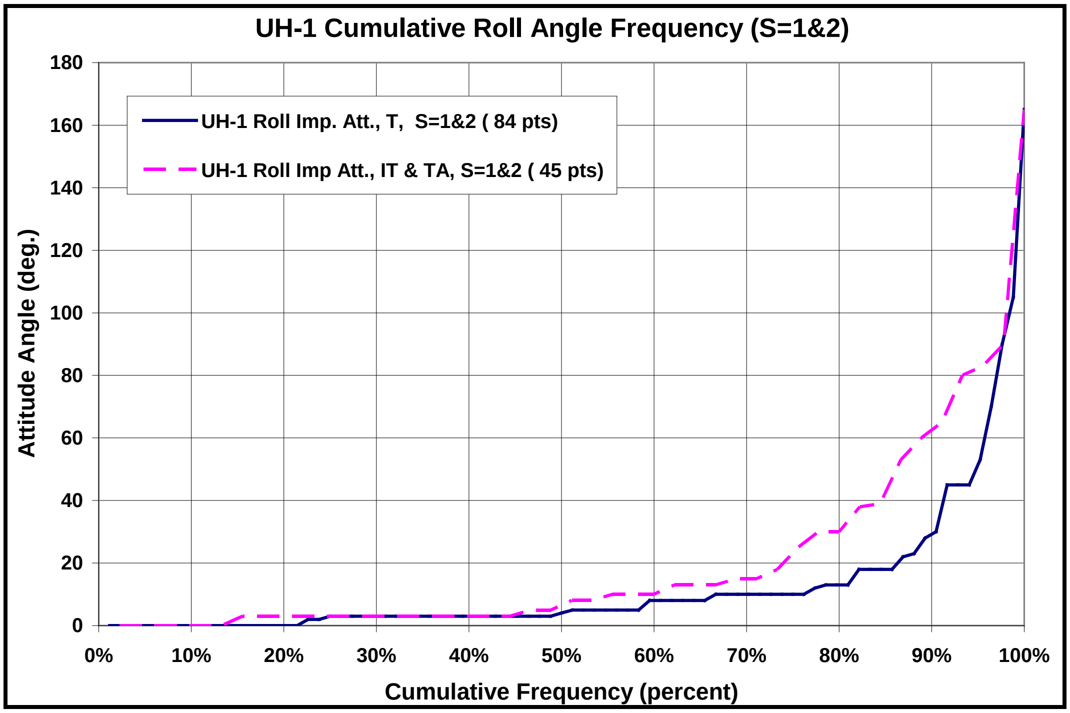

Figure D-79 – UH-1 Cumulative Roll Angle Frequency (S=1&2)

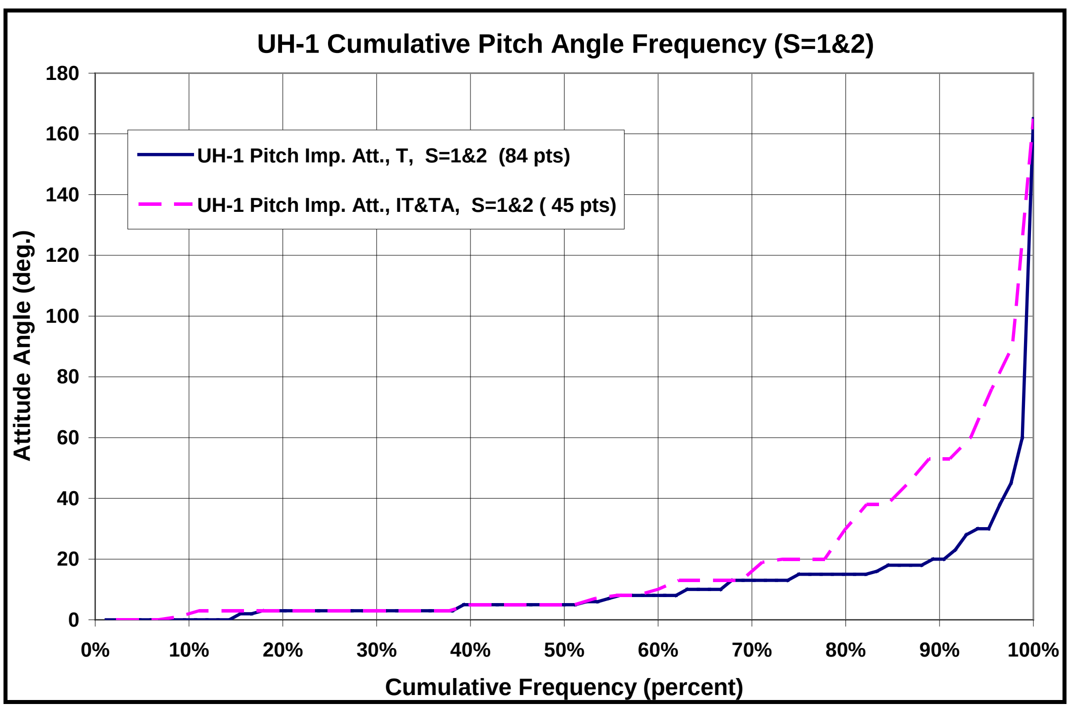

Figure D-80 – UH-1 Cumulative Pitch Angle Frequency (S=1&2)

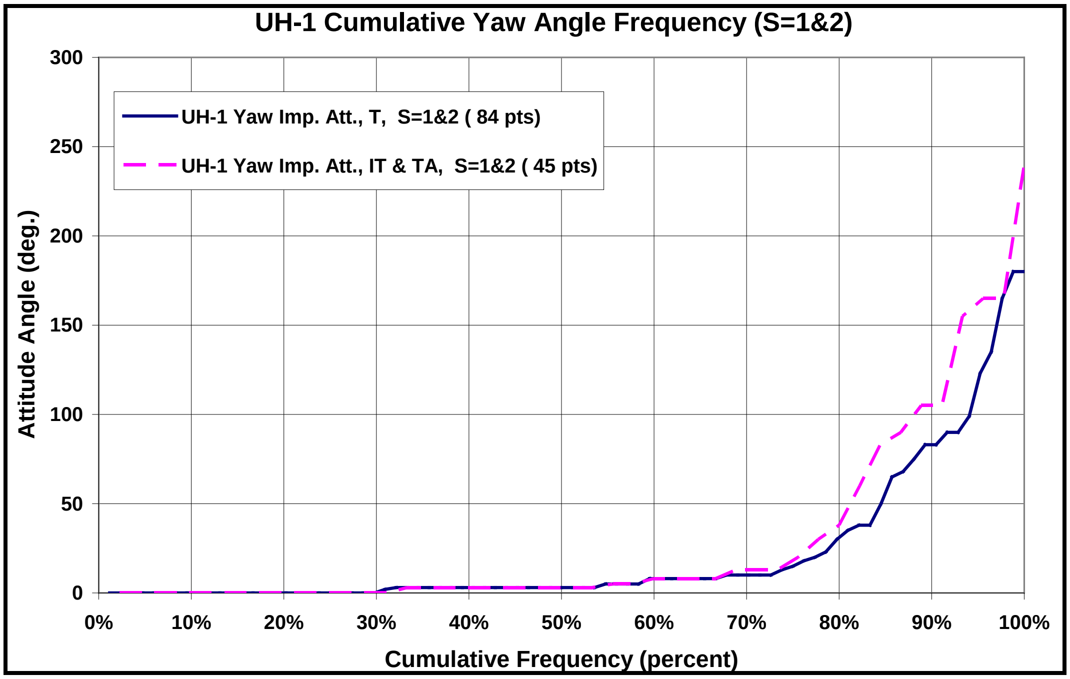

Figure D-81 – UH-1 Cumulative Yaw Angle Frequency (S=1&2)

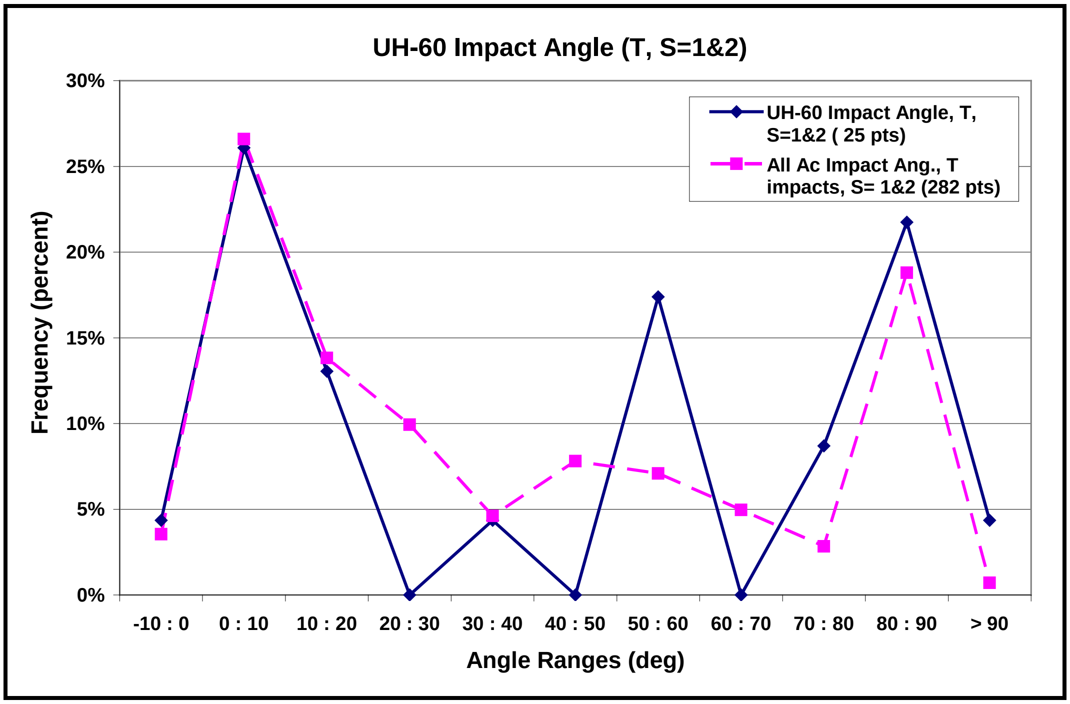

Figure D-82 – UH-60 Impact Angle (T, S=1&2)

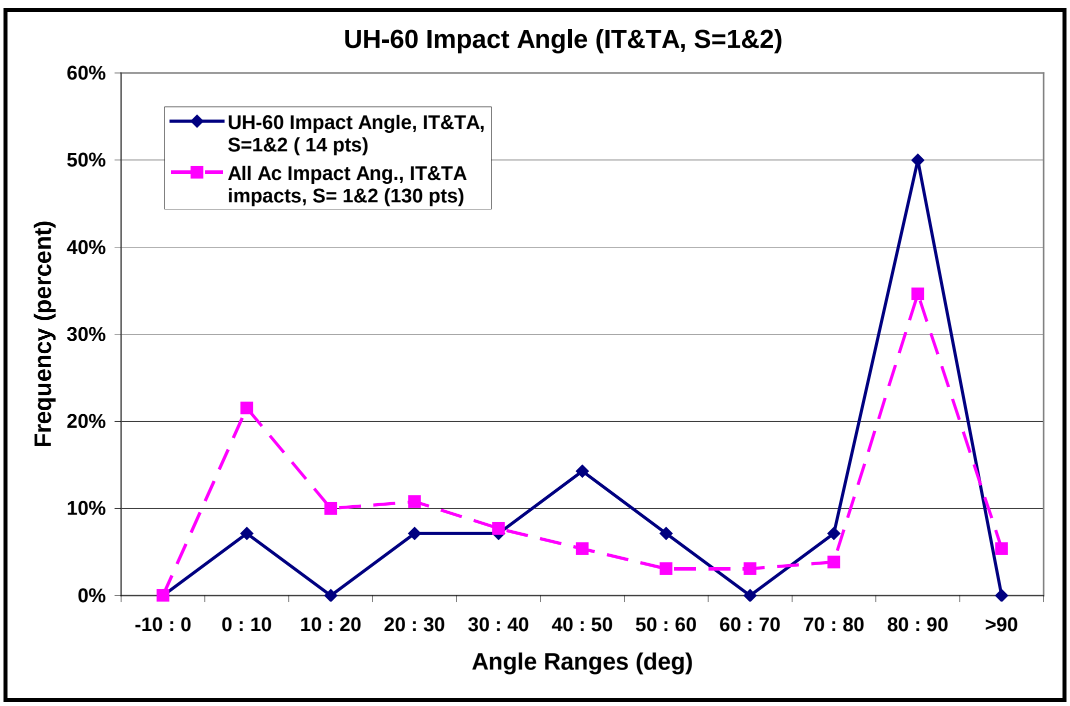

Figure D-83 – UH-60 Impact Angle (IT&TA, S=1&2)

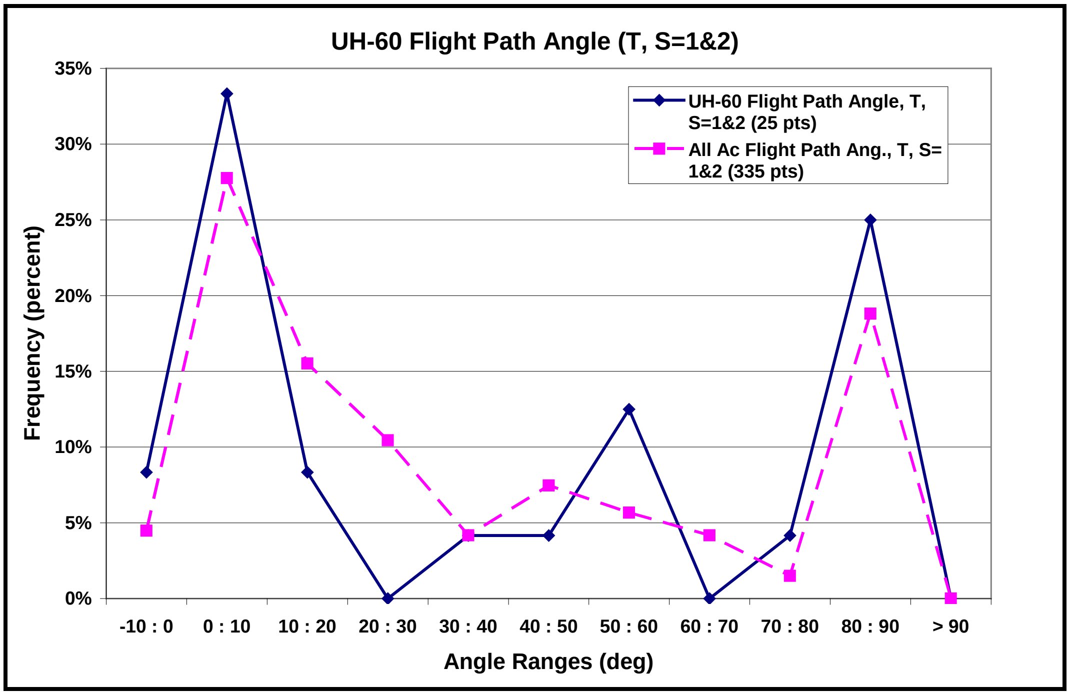

Figure D-84 – UH-60 Flight Path Angle (T, S=1&2)

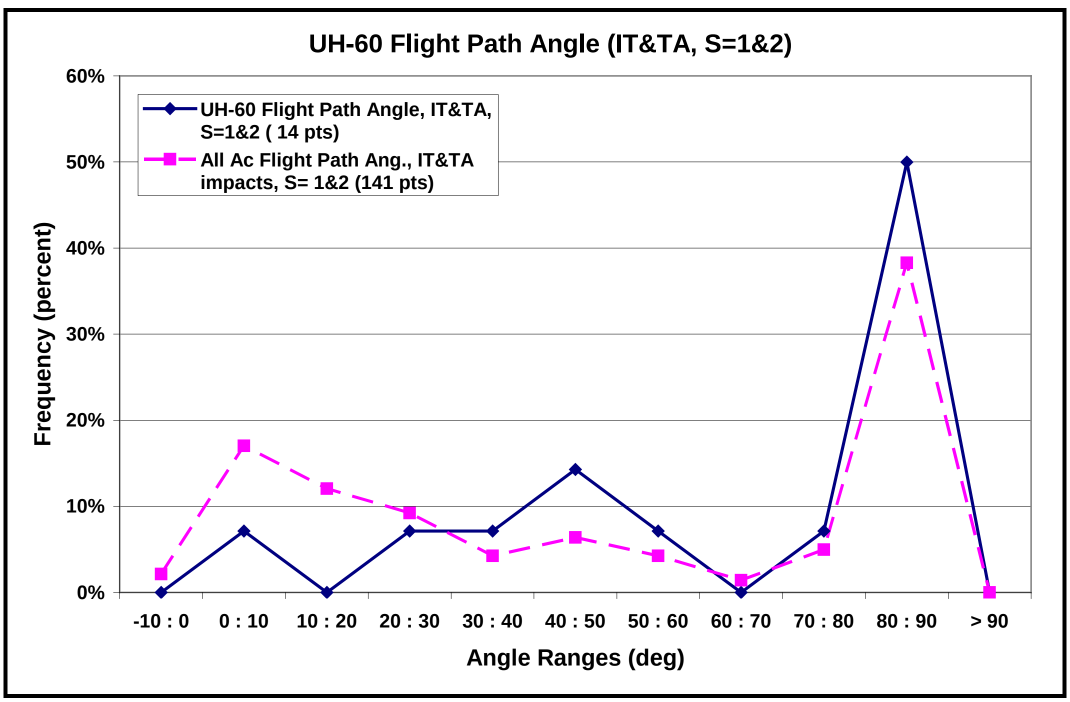

Figure D-85 – UH-60 Flight Path Angle (IT&TA, S=1&2)

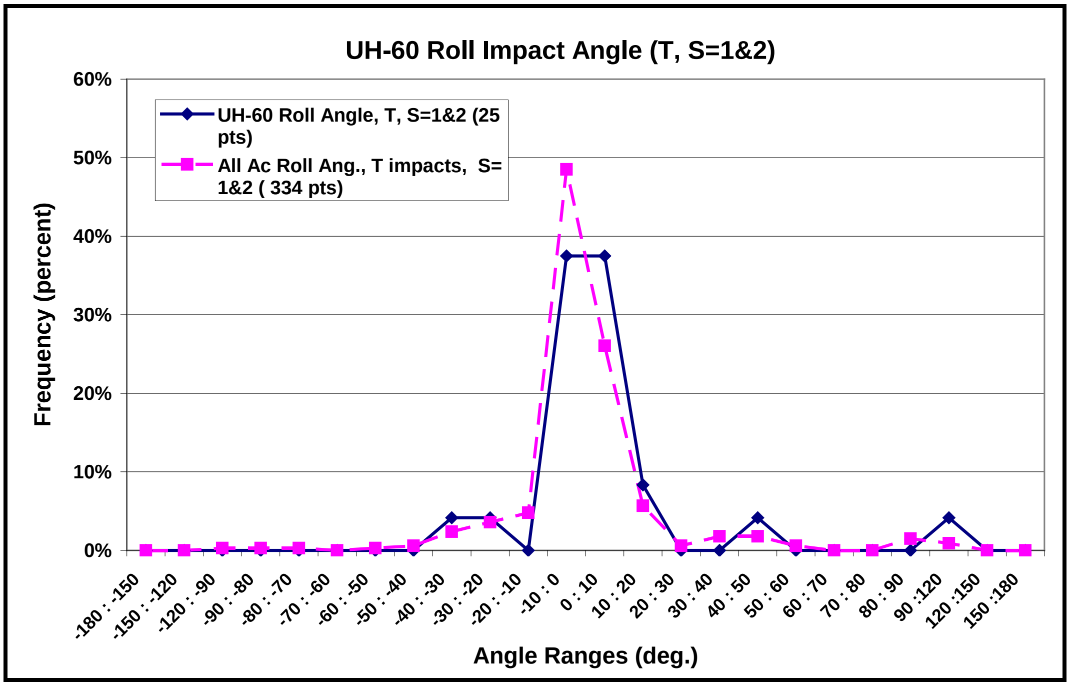

Figure D-86 – UH-60 Roll Attitude Angle (T, S=1&2)

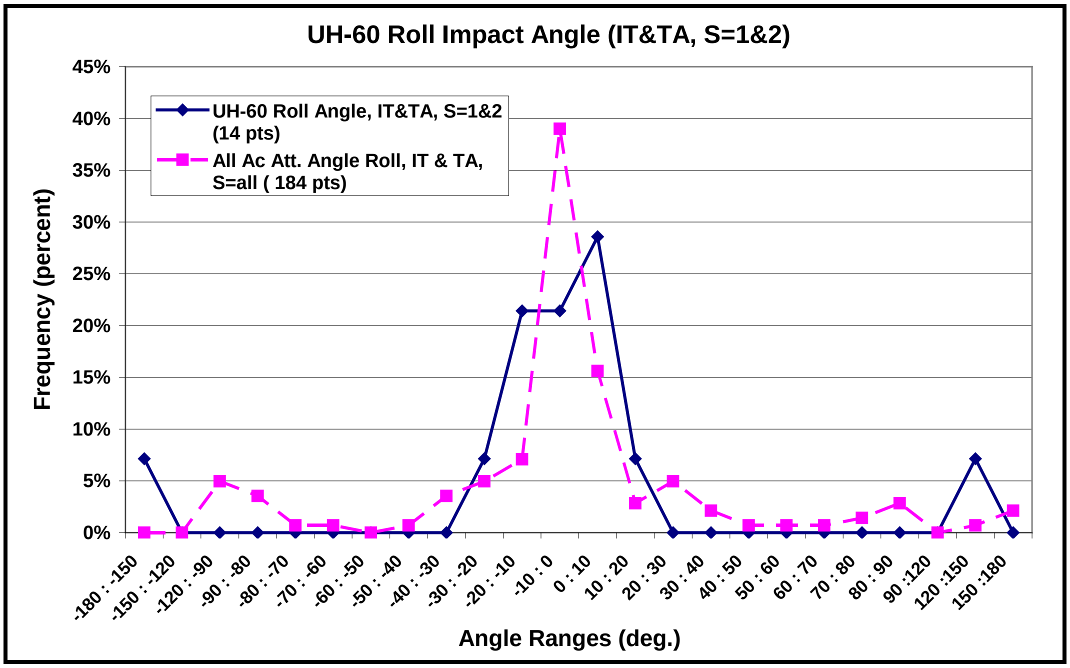

Figure D-87 – UH-60 Roll Attitude Angle (IT&TA, S=1&2)

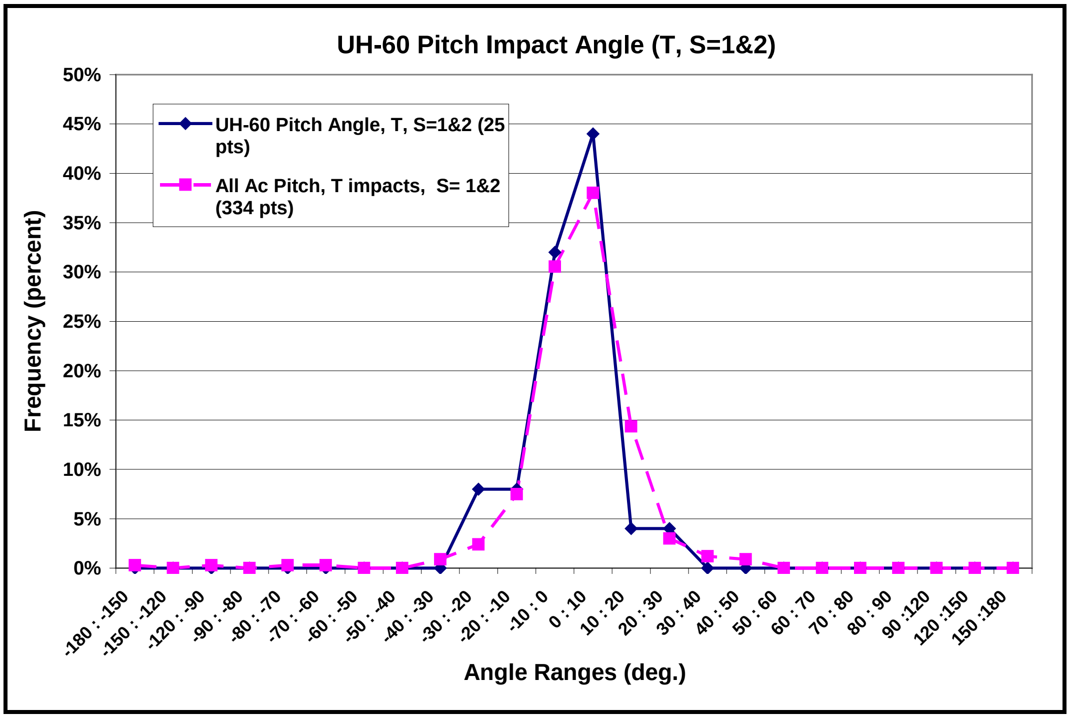

Figure D-88 – UH-60 Pitch Attitude Angle (T, S=1&2)

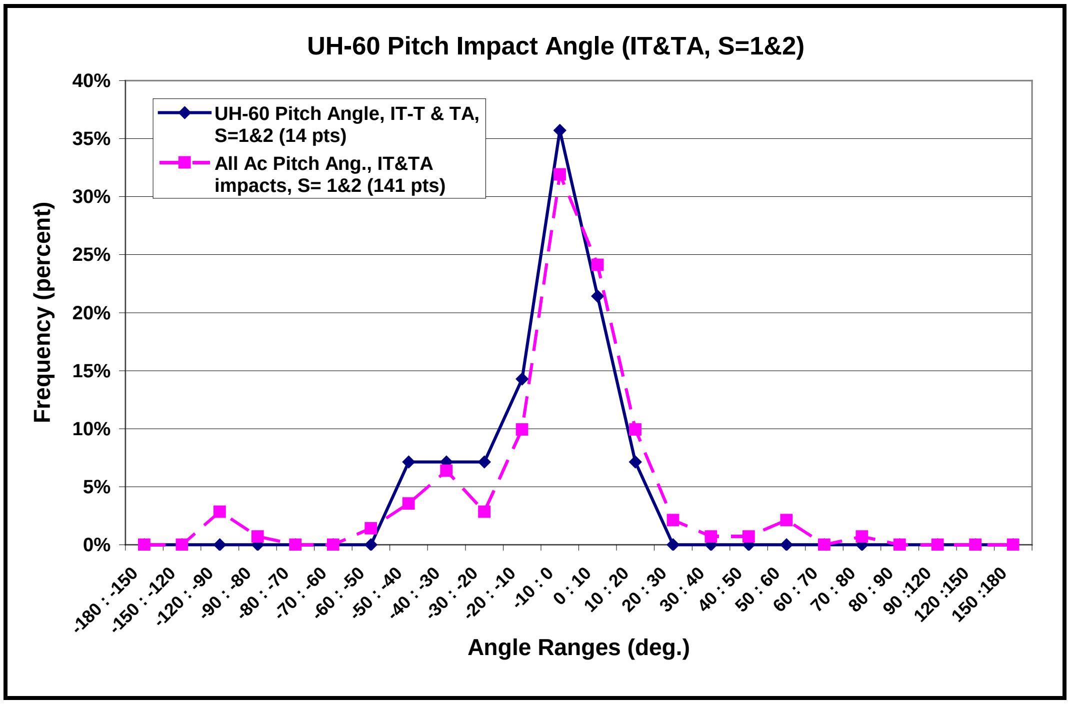

Figure D-89 – UH-60 Pitch Attitude Angle (IT&TA, S=1&2)

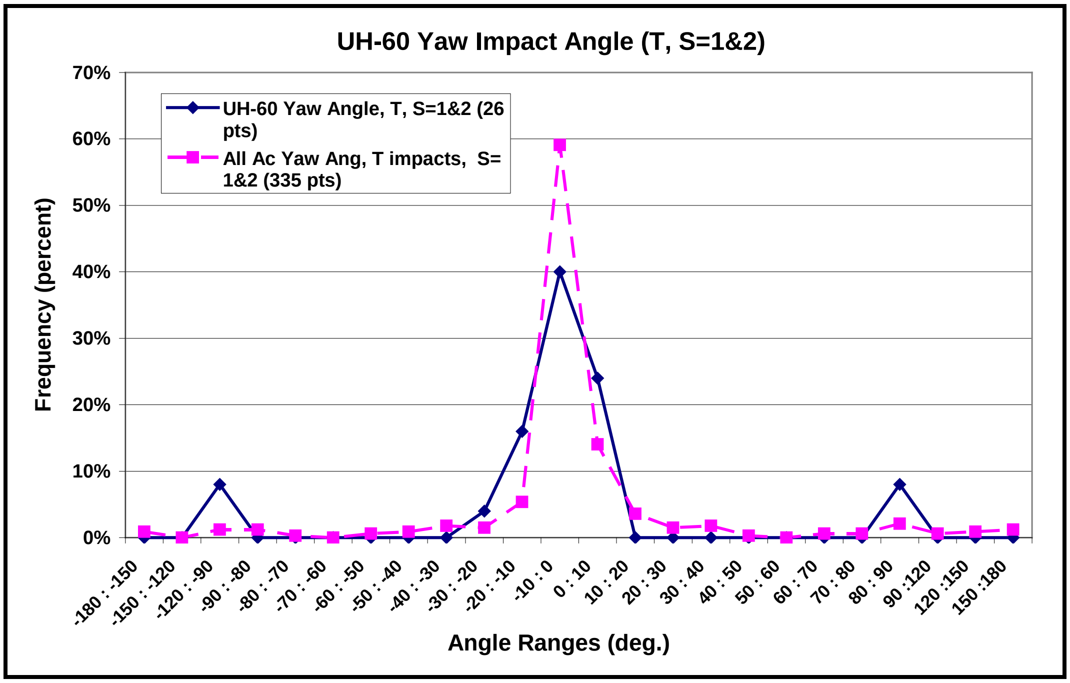

Figure D-90 – UH-60 Yaw Attitude Angle (T, S=1&2)

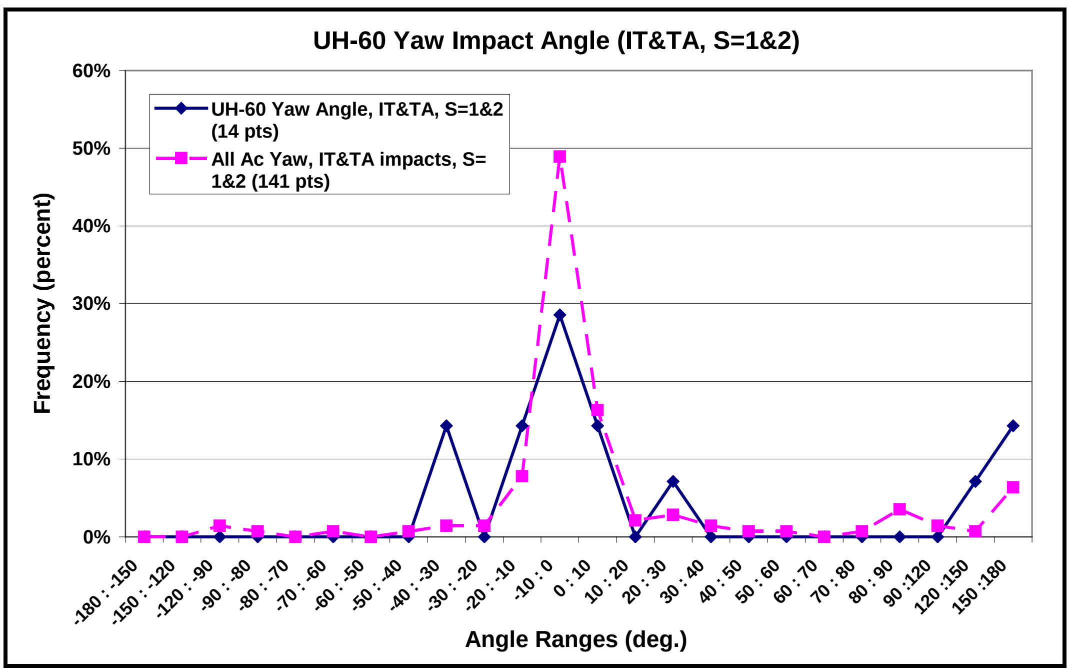

Figure D-91 – UH-60 Yaw Attitude Angle (IT&TA, S=1&2)

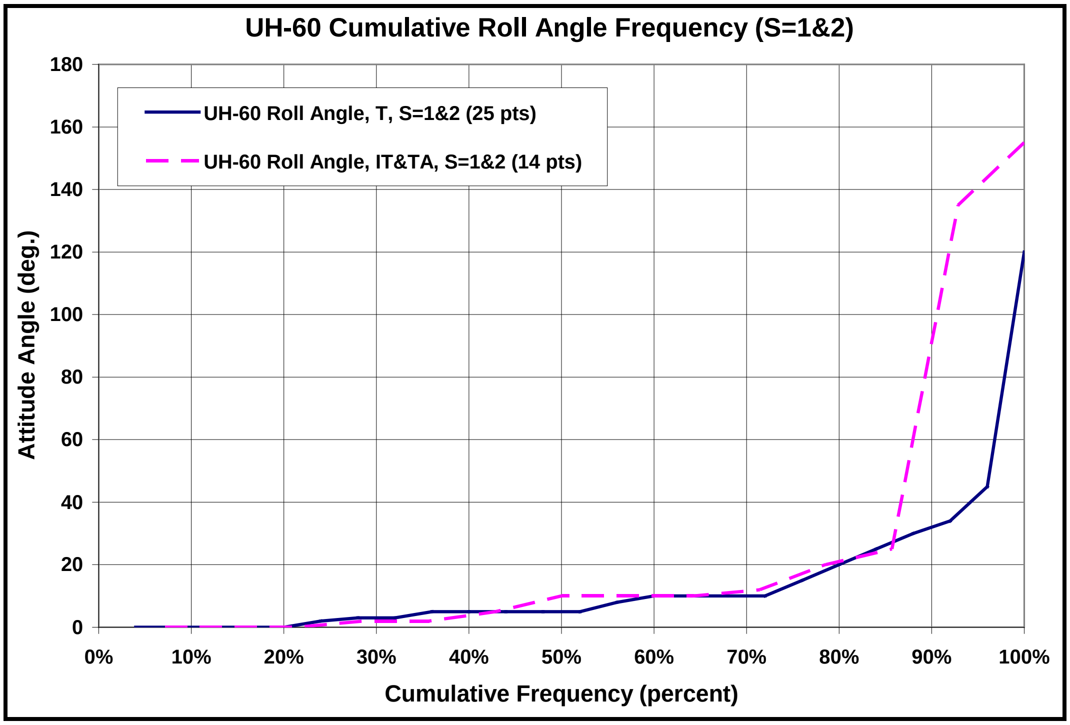

Figure D-92 – UH-60 Cumulative Roll Angle Frequency (S=1&2)

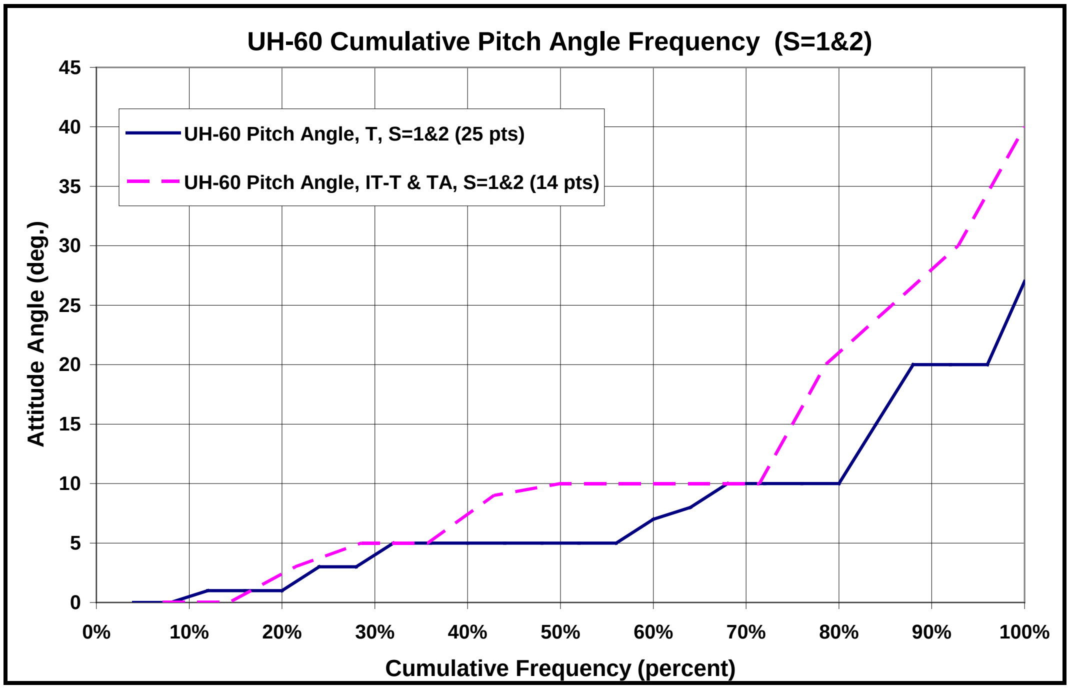

Figure D-93 – UH-60 Cumulative Pitch Angle Frequency (S=1&2)

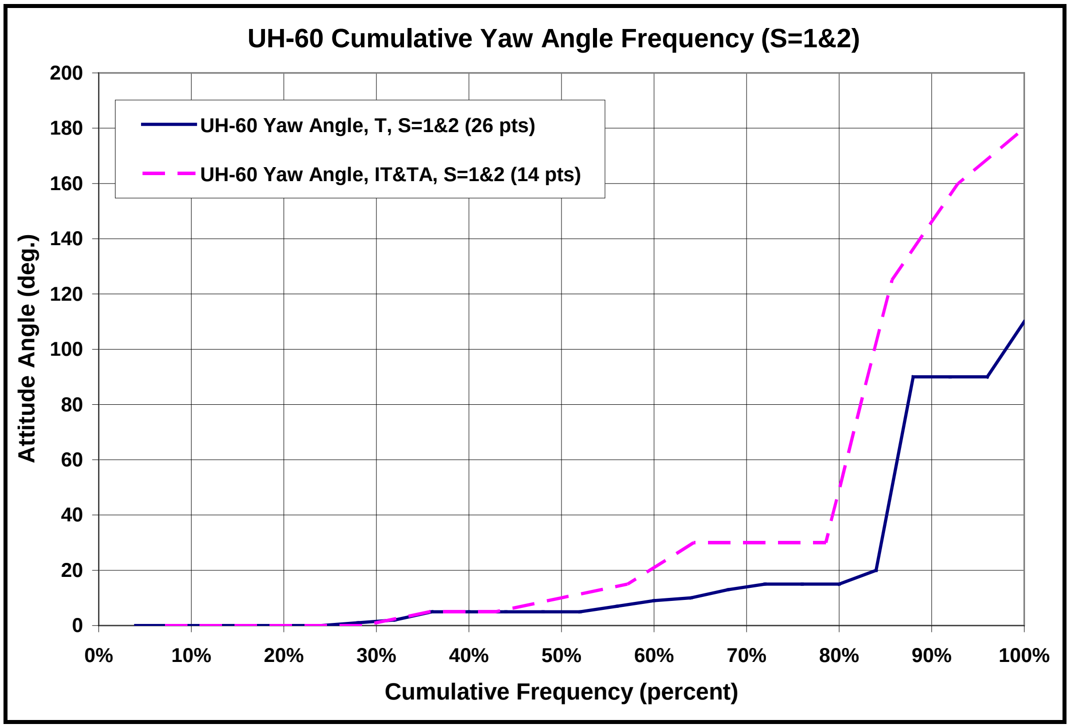

Figure D-94 – UH-60 Cumulative Yaw Angle Frequency (S=1&2)

Appendix E – Phase of Operation Tables

The tables in Appendix E present the detail data of the phase from the operation query. Descriptors for the phase of operation are recorded at three segments in the accident sequence: planned, when the emergency occurs, and accident or termination.

For the “planned” phase, the guidelines instruct the investigator to enter the flight phase that was intended during preflight planning for that segment of the mission profile in which the emergency occurred. For the "emergency" segment, the guidelines instruct that the investigator report the phase "at the time of the emergency." For the “accident or termination, ‘the descriptors applicable’ at the time when the major impact/accident occurred or accident sequence stops” are to be recorded. In each of the three segments, up to three descriptors can be recorded. In the following tables the phase descriptors are listed down the left column.

In the next three columns (labeled P-1, P-2, P-3), the number in the P-1 column corresponding to each descriptor presents the number of times that the specific descriptor was listed as the first “planned” descriptor for that aircraft type. Likewise the column P-2 presents the number of times that descriptor was listed as the second planned descriptor. The three rows above the descriptor list provide information on overall counts, the first row gives number of records or crashes that reported phase of operation data. The second row gives a count of the number of records in which that field was left blank and the third row gives a count of the number of records for which that field contained data. The reader will see that the planned (P) segment was generally not populated with data. For the emergency (E) and the termination (T) segments, the first field is most often populated, the second field less often and the third field least often.

Table E-1 – Phase of Operation, AH-1_T

AH-1_T	P-1	P-2	P-3	E-1	E-2	E-3	T-1	T-2	T-3
No. of Records	65	65	65	65	65	65	65	65	65
No. of Blank Records	64	65	65	12	52	64	10	40	64
No. of Records with Data	1	0	0	53	13	1	55	25	1
Phase Designators									
Climb at Take-off	0	0	0	0	0	0	0	0	0
Takeoff	0	0	0	5	0	0	2	0	0
Cruise	1	0	0	17	0	0	2	0	0
Turning	0	0	0	0	2	0	0	0	0
Formation	0	0	0	0	0	0	0	0	0
Landing Aircraft	0	0	0	13	1	0	40	0	0
Hover in Ground Effect	0	0	0	1	0	0	1	0	0
Hover out of Ground Effect	0	0	0	0	0	0	0	0	0
Low Level	0	0	0	8	0	1	2	0	1
Approach	0	0	0	2	0	0	1	0	0
Training Autorotation	0	0	0	0	9	0	0	6	0
Emergency Autorotation	0	0	0	1	0	0	1	19	0
Power Recovery	0	0	0	0	0	0	0	0	0
Crash	0	0	0	0	0	0	0	0	0
Contour	0	0	0	0	0	0	0	0	0
Go around/ TALS Abort	0	0	0	1	0	0	1	0	0
Nap of Earth	0	0	0	2	0	0	0	0	0
Descent	0	0	0	1	0	0	4	0	0
Aerobatics	0	0	0	1	0	0	0	0	0
Deceleration	0	0	0	0	1	0	0	0	0
Combat Maneuver	0	0	0	0	0	0	0	0	0
Static Engine Run	0	0	0	1	0	0	1	0	0
Taxi	0	0	0	0	0	0	0	0	0
Termination	0	0	0	0	0	0	0	0	0
Total Data	**1**	**0**	**0**	**53**	**13**	**1**	**55**	**25**	**1**

Table E-2 – Phase of Operation, AH-1_IT&TA

AH-1_IT&TA	P-1	P-2	P-3	E-1	E-2	E-3	T-1	T-2	T-3
No. of Records	26	26	26	26	26	26	26	26	26
No. of Blank Records	26	26	26	12	21	26	0	17	26
No. of Records with Data	0	0	0	14	5	0	26	9	0
Phase Designators									
Climb at Take-off	0	0	0	0	0	0	0	0	0
Takeoff	0	0	0	2	0	0	0	0	0
Cruise	0	0	0	1	0	0	0	0	0
Turning	0	0	0	0	5	0	0	4	0
Formation	0	0	0	0	0	0	0	1	0
Landing Aircraft	0	0	0	0	0	0	5	4	0
Hover in Ground Effect	0	0	0	1	0	0	0	0	0
Hover out of Ground Effect	0	0	0	3	0	0	4	0	0
Low Level	0	0	0	5	0	0	8	0	0
Approach	0	0	0	0	0	0	1	0	0
Training Autorotation	0	0	0	0	0	0	0	0	0
Emergency Autorotation	0	0	0	0	0	0	5	0	0
Power Recovery	0	0	0	0	0	0	0	0	0
Crash	0	0	0	0	0	0	0	0	0
Contour	0	0	0	0	0	0	0	0	0
Go around/ TALS Abort	0	0	0	0	0	0	0	0	0
NAP OF EARTH	0	0	0	1	0	0	0	0	0
Descent	0	0	0	1	0	0	3	0	0
Aerobatics	0	0	0	0	0	0	0	0	0
Deceleration	0	0	0	0	0	0	0	0	0
Combat Maneuver	0	0	0	0	0	0	0	0	0
Static Engine Run	0	0	0	0	0	0	0	0	0
Taxi	0	0	0	0	0	0	0	0	0
Termination	0	0	0	0	0	0	0	0	0
Total Data	**0**	**0**	**0**	**14**	**5**	**0**	**26**	**9**	**0**

Table E-3 – Phase of Operation, AH-64_T

AH-64_T	P-1	P-2	P-3	E-1	E-2	E-3	T-1	T-2	T-3
No. of Records	42	42	42	42	42	42	42	42	42
No. of Blank Records	32	42	42	3	39	41	3	37	42
No. of Records with Data	10	0	0	39	3	1	39	5	0
Phase Designators									
Climb at Take-off	0	0	0	0	0	0	0	0	0
Takeoff	0	0	0	2	0	0	1	0	0
Cruise	4	0	0	8	0	0	0	0	0
Turning	0	0	0	0	0	0	0	0	0
Formation	2	0	0	1	0	1	0	0	0
Landing Aircraft	0	0	0	0	0	0	7	3	0
Hover in Ground Effect	0	0	0	1	0	0	1	0	0
Hover out of Ground Effect	0	0	0	11	2	0	1	0	0
Low Level	3	0	0	1	1	0	0	0	0
Approach	1	0	0	1	0	0	0	0	0
Training Autorotation	0	0	0	0	0	0	0	1	0
Emergency Autorotation	0	0	0	0	0	0	4	0	0
Power Recovery	0	0	0	0	0	0	0	0	0
Crash	0	0	0	0	0	0	14	1	0
Contour	0	0	0	1	0	0	1	0	0
Go around/ TALS Abort	0	0	0	1	0	0	2	0	0
NAP OF EARTH	0	0	0	1	0	0	0	0	0
Descent	0	0	0	2	0	0	6	0	0
Aerobatics	0	0	0	0	0	0	0	0	0
Deceleration	0	0	0	0	0	0	0	0	0
Combat Maneuver	0	0	0	7	0	0	1	0	0
Static Engine Run	0	0	0	2	0	0	1	0	0
Taxi	0	0	0	0	0	0	0	0	0
Termination	0	0	0	0	0	0	0	0	0
Total Data	**10**	**0**	**0**	**39**	**3**	**1**	**39**	**5**	**0**

Table E-4 – Phase of Operation, AH-64_IT&TA

AH-64_IT&TA	P-1	P-2	P-3	E-1	E-2	E-3	T-1	T-2	T-3
No. of Records	24	24	24	24	24	24	24	24	24
No. of Blank Records	19	23	24	1	20	24	0	22	23
No. of Records with Data	5	1	0	23	4	0	24	2	1
Phase Designators									
Climb at Take-off	0	0	0	1	0	0	0	0	0
Takeoff	0	0	0	1	0	0	0	0	0
Cruise	1	0	0	6	0	0	1	0	0
Turning	0	0	0	0	0	0	0	0	0
Formation	0	1	0	0	3	0	0	0	0
Landing Aircraft	0	0	0	0	0	0	5	1	1
Hover in Ground Effect	0	0	0	1	0	0	0	0	0
Hover out of Ground Effect	0	0	0	3	0	0	1	0	0
Low Level	2	0	0	3	1	0	0	0	0
Approach	0	0	0	3	0	0	2	0	0
Training Autorotation	0	0	0	0	0	0	0	0	0
Emergency Autorotation	0	0	0	0	0	0	1	1	0
Power Recovery	0	0	0	0	0	0	0	0	0
Crash	0	0	0	1	0	0	9	0	0
Contour	1	0	0	2	0	0	2	0	0
Go around/ TALS Abort	0	0	0	0	0	0	0	0	0
NAP OF EARTH	0	0	0	1	0	0	0	0	0
Descent	0	0	0	1	0	0	2	0	0
Aerobatics	0	0	0	0	0	0	0	0	0
Deceleration	0	0	0	0	0	0	0	0	0
Combat Maneuver	1	0	0	0	0	0	0	0	0
Static Engine Run	0	0	0	0	0	0	1	0	0
Taxi	0	0	0	0	0	0	0	0	0
Termination	0	0	0	0	0	0	0	0	0
Total Data	**5**	**1**	**0**	**23**	**4**	**0**	**24**	**2**	**1**

Table E-5 – Phase of Operation, CH-47_T

CH-47_T	P-1	P-2	P-3	E-1	E-2	E-3	T-1	T-2	T-3
No. of Records	21	21	21	21	21	21	21	21	21
No. of Blank Records	18	20	21	1	16	21	0	17	21
No. of Records with Data	3	1	0	20	5	0	21	4	0
Phase Designators									
Climb at Take-off	0	0	0	1	0	0	1	0	0
Takeoff	1	0	0	2	0	0	1	0	0
Cruise	1	0	0	6	0	0	0	0	0
Turning	0	0	0	0	0	0	0	0	0
Formation	0	0	0	0	2	0	0	0	0
Landing Aircraft	0	0	0	2	2	0	11	2	0
Hover in Ground Effect	0	0	0	1	0	0	0	0	0
Hover out of Ground Effect	0	0	0	0	0	0	0	0	0
Low Level	1	0	0	0	0	0	0	0	0
Approach	0	0	0	4	0	0	2	0	0
Training Autorotation	0	0	0	0	1	0	0	0	0
Emergency Autorotation	0	0	0	0	0	0	1	2	0
Power Recovery	0	0	0	0	0	0	0	0	0
Crash	0	0	0	0	0	0	5	0	0
Contour	0	1	0	0	0	0	0	0	0
Go around/ TALS Abort	0	0	0	2	0	0	0	0	0
NAP OF EARTH	0	0	0	0	0	0	0	0	0
Descent	0	0	0	2	0	0	0	0	0
Aerobatics	0	0	0	0	0	0	0	0	0
Deceleration	0	0	0	0	0	0	0	0	0
Combat Maneuver	0	0	0	0	0	0	0	0	0
Static Engine Run	0	0	0	0	0	0	0	0	0
Taxi	0	0	0	0	0	0	0	0	0
Termination	0	0	0	0	0	0	0	0	0
Total Data	**3**	**1**	**0**	**20**	**5**	**0**	**21**	**4**	**0**

Table E-6 – Phase of Operation, CH-47_IT&TA

CH-47_IT&TA									
No. of Records	3	3	3	3	3	3	3	3	3
No. of Blank Records	3	3	3	1	1	3	0	1	3
No. of Records with Data	0	0	0	2	2	0	3	2	0
Phase Designators									
Climb at Take-off	0	0	0	0	0	0	0	0	0
Takeoff	0	0	0	1	0	0	0	0	0
Cruise	0	0	0	0	0	0	0	0	0
Turning	0	0	0	0	2	0	0	2	0
Formation	0	0	0	0	0	0	0	0	0
Landing Aircraft	0	0	0	0	0	0	0	0	0
Hover in Ground Effect	0	0	0	0	0	0	0	0	0
Hover out of Ground Effect	0	0	0	0	0	0	0	0	0
Low Level	0	0	0	0	0	0	1	0	0
Approach	0	0	0	0	0	0	0	0	0
Training Autorotation	0	0	0	0	0	0	0	0	0
Emergency Autorotation	0	0	0	0	0	0	0	0	0
Power Recovery	0	0	0	0	0	0	0	0	0
Crash	0	0	0	0	0	0	0	0	0
Contour	0	0	0	0	0	0	0	0	0
Go around/ TALS Abort	0	0	0	0	0	0	0	0	0
NAP OF EARTH	0	0	0	0	0	0	0	0	0
Descent	0	0	0	1	0	0	2	0	0
Aerobatics	0	0	0	0	0	0	0	0	0
Deceleration	0	0	0	0	0	0	0	0	0
Combat Maneuver	0	0	0	0	0	0	0	0	0
Static Engine Run	0	0	0	0	0	0	0	0	0
Taxi	0	0	0	0	0	0	0	0	0
Termination	0	0	0	0	0	0	0	0	0
Total Data	**0**	**0**	**0**	**2**	**2**	**0**	**3**	**2**	**0**

Table E-7 – Phase of Operation, OH-6_T

OH-6_T	P-1	P-2	P-3	E-1	E-2	E-3	T-1	T-2	T-3
No. of Records	29	29	29	29	29	29	29	29	29
No. of Blank Records	28	28	29	7	22	28	4	11	27
No. of Records with Data	1	1	0	22	7	1	25	18	2
Phase Designators									
Climb at Take-off	0	0	0	0	0	0	0	0	0
Takeoff	0	0	0	2	0	0	0	0	0
Cruise	0	0	0	7	0	0	0	0	0
Turning	0	1	0	0	3	1	0	1	0
Formation	0	0	0	0	0	0	0	0	0
Landing Aircraft	0	0	0	5	1	0	12	11	0
Hover in Ground Effect	0	0	0	0	0	0	1	0	0
Hover out of Ground Effect	0	0	0	1	0	0	0	0	0
Low Level	0	0	0	4	0	0	1	0	1
Approach	0	0	0	2	0	0	0	0	0
Training Autorotation	0	0	0	0	3	0	0	6	0
Emergency Autorotation	0	0	0	1	0	0	11	0	1
Power Recovery	0	0	0	0	0	0	0	0	0
Crash	0	0	0	0	0	0	0	0	0
Contour	0	0	0	0	0	0	0	0	0
Go around/ TALS Abort	0	0	0	0	0	0	0	0	0
NAP OF EARTH	0	0	0	0	0	0	0	0	0
Descent	1	0	0	0	0	0	0	0	0
Aerobatics	0	0	0	0	0	0	0	0	0
Deceleration	0	0	0	0	0	0	0	0	0
Combat Maneuver	0	0	0	0	0	0	0	0	0
Static Engine Run	0	0	0	0	0	0	0	0	0
Taxi	0	0	0	0	0	0	0	0	0
Termination	0	0	0	0	0	0	0	0	0
Total Data	**1**	**1**	**0**	**22**	**7**	**1**	**25**	**18**	**2**

Table E-8 – Phase of Operation, OH-6_IT&TA

OH-6_IT&TA	P-1	P-2	P-3	E-1	E-2	E-3	T-1	T-2	T-3
No. of Records	3	3	3	3	3	3	3	3	3
No. of Blank Records	3	3	3	1	3	3	0	1	3
No. of Records with Data	0	0	0	2	0	0	3	2	0
Phase Designators									
Climb at Take-off	0	0	0	0	0	0	0	0	0
Takeoff	0	0	0	0	0	0	0	0	0
Cruise	0	0	0	1	0	0	1	0	0
Turning	0	0	0	0	0	0	0	0	0
Formation	0	0	0	0	0	0	0	1	0
Landing Aircraft	0	0	0	0	0	0	1	0	0
Hover in Ground Effect	0	0	0	1	0	0	0	0	0
Hover out of Ground Effect	0	0	0	0	0	0	0	0	0
Low Level	0	0	0	0	0	0	1	0	0
Approach	0	0	0	0	0	0	0	0	0
Training Autorotation	0	0	0	0	0	0	0	0	0
Emergency Autorotation	0	0	0	0	0	0	0	1	0
Power Recovery	0	0	0	0	0	0	0	0	0
Crash	0	0	0	0	0	0	0	0	0
Contour	0	0	0	0	0	0	0	0	0
Go around/ TALS Abort	0	0	0	0	0	0	0	0	0
NAP OF EARTH	0	0	0	0	0	0	0	0	0
Descent	0	0	0	0	0	0	0	0	0
Aerobatics	0	0	0	0	0	0	0	0	0
Deceleration	0	0	0	0	0	0	0	0	0
Combat Maneuver	0	0	0	0	0	0	0	0	0
Static Engine Run	0	0	0	0	0	0	0	0	0
Taxi	0	0	0	0	0	0	0	0	0
Termination	0	0	0	0	0	0	0	0	0
Total Data	**0**	**0**	**0**	**2**	**0**	**0**	**3**	**2**	**0**

Table E-9 – Phase of Operation, OH-58AC_T

OH-58AC_T	P-1	P-2	P-3	E-1	E-2	E-3	T-1	T-2	T-3
No. of Records	81	81	81	81	81	81	81	81	81
No. of Blank Records	75	79	79	8	61	79	12	55	80
No. of Records with Data	6	2	2	73	20	2	69	26	1
Phase Designators									
Climb at Take-off	0	0	0	3	0	0	2	0	0
Takeoff	2	0	0	9	0	0	5	0	0
Cruise	2	0	0	13	0	0	3	0	0
Turning	0	0	0	1	12	0	0	4	1
Formation	0	0	1	0	0	1	0	1	0
Landing Aircraft	1	0	0	6	1	0	24	18	0
Hover in Ground Effect	0	0	0	11	0	0	5	0	0
Hover out of Ground Effect	0	0	0	2	0	0	0	0	0
Low Level	1	2	0	10	3	0	1	0	0
Approach	0	0	0	8	0	0	2	0	0
Training Autorotation	0	0	0	1	2	0	0	3	0
Emergency Autorotation	0	0	1	1	1	0	19	0	0
Power Recovery	0	0	0	0	0	0	0	0	0
Crash	0	0	0	0	0	0	4	0	0
Contour	0	0	0	1	0	0	0	0	0
Go around/ TALS Abort	0	0	0	1	0	0	0	0	0
NAP OF EARTH	0	0	0	1	0	0	0	0	0
Descent	0	0	0	4	1	0	4	0	0
Aerobatics	0	0	0	0	0	0	0	0	0
Deceleration	0	0	0	0	0	1	0	0	0
Combat Maneuver	0	0	0	1	0	0	0	0	0
Static Engine Run	0	0	0	0	0	0	0	0	0
Taxi	0	0	0	0	0	0	0	0	0
Termination	0	0	0	0	0	0	0	0	0
Total Data	**6**	**2**	**2**	**73**	**20**	**2**	**69**	**26**	**1**

Table E-10 – Phase of Operation, OH-58AC_IT&TA

OH-58AC_IT&TA	P-1	P-2	P-3	E-1	E-2	E-3	T-1	T-2	T-3
No. of Records	41	41	41	41	41	41	41	41	41
No. of Blank Records	39	41	41	16	35	41	3	26	39
No. of Records with Data	2	0	0	25	6	0	38	15	2
Phase Designators									
Climb at Take-off	0	0	0	0	0	0	2	0	0
Takeoff	0	0	0	0	0	0	2	0	0
Cruise	1	0	0	6	0	0	3	0	0
Turning	0	0	0	0	2	0	0	5	1
Formation	0	0	0	0	0	0	0	0	0
Landing Aircraft	0	0	0	2	2	0	7	7	1
Hover in Ground Effect	0	0	0	2	0	0	1	0	0
Hover out of Ground Effect	1	0	0	1	0	0	0	0	0
Low Level	0	0	0	8	1	0	9	1	0
Approach	0	0	0	1	0	0	2	0	0
Training Autorotation	0	0	0	0	0	0	0	0	0
Emergency Autorotation	0	0	0	1	0	0	8	1	0
Power Recovery	0	0	0	0	0	0	0	0	0
Crash	0	0	0	0	0	0	1	0	0
Contour	0	0	0	1	0	0	0	0	0
Go around/ TALS Abort	0	0	0	0	0	0	0	0	0
NAP OF EARTH	0	0	0	2	1	0	2	0	0
Descent	0	0	0	0	0	0	1	0	0
Aerobatics	0	0	0	0	0	0	0	0	0
Deceleration	0	0	0	0	0	0	0	1	0
Combat Maneuver	0	0	0	1	0	0	0	0	0
Static Engine Run	0	0	0	0	0	0	0	0	0
Taxi	0	0	0	0	0	0	0	0	0
Termination	0	0	0	0	0	0	0	0	0
Total Data	**2**	**0**	**0**	**25**	**6**	**0**	**38**	**15**	**2**

Table E-11 – Phase of Operation, OH-58D_T

OH-58D_T	P-1	P-2	P-3	E-1	E-2	E-3	T-1	T-2	T-3
No. of Records	33	33	33	33	33	33	33	33	33
No. of Blank Records	22	30	33	0	27	33	6	26	33
No. of Records with Data	11	3	0	33	6	0	27	7	0
Phase Designators									
Climb at Take-off	0	0	0	1	0	0	0	0	0
Takeoff	2	0	0	4	0	0	2	0	0
Cruise	3	0	0	6	0	0	1	0	0
Turning	0	0	0	0	0	0	0	0	0
Formation	0	0	0	0	0	0	0	0	0
Landing Aircraft	1	0	0	1	1	0	5	4	0
Hover in Ground Effect	1	0	0	2	0	0	1	0	0
Hover out of Ground Effect	0	0	0	1	0	0	0	0	0
Low Level	2	0	0	1	0	0	0	0	0
Approach	1	0	0	3	0	0	1	0	0
Training Autorotation	0	2	0	2	4	0	0	3	0
Emergency Autorotation	0	0	0	4	0	0	9	0	0
Power Recovery	0	0	0	0	1	0	0	0	0
Crash	0	0	0	0	0	0	6	0	0
Contour	0	0	0	1	0	0	1	0	0
Go around/ TALS Abort	0	0	0	0	0	0	0	0	0
NAP OF EARTH	0	0	0	0	0	0	0	0	0
Descent	1	0	0	2	0	0	0	0	0
Aerobatics	0	0	0	0	0	0	0	0	0
Deceleration	0	0	0	0	0	0	0	0	0
Combat Maneuver	0	1	0	1	0	0	1	0	0
Static Engine Run	0	0	0	0	0	0	0	0	0
Taxi	0	0	0	0	0	0	0	0	0
Termination	0	0	0	4	0	0	0	0	0
Total Data	**11**	**3**	**0**	**33**	**6**	**0**	**27**	**7**	**0**

Table E-12 – Phase of Operation, OH-58D_IT&TA

OH-58D_IT&TA	P-1	P-2	P-3	E-1	E-2	E-3	T-1	T-2	T-3
No. of Records	12	12	12	12	12	12	12	12	12
No. of Blank Records	8	10	12	0	9	12	0	11	11
No. of Records with Data	4	2	0	12	3	0	12	1	1
Phase Designators									
Climb at Take-off	0	0	0	0	0	0	0	0	0
Takeoff	0	0	0	0	0	0	0	0	0
Cruise	0	0	0	1	0	0	1	0	0
Turning	0	0	0	0	0	0	0	0	0
Formation	0	0	0	0	0	0	0	0	0
Landing Aircraft	0	0	0	1	0	0	0	1	0
Hover in Ground Effect	0	0	0	1	0	0	1	0	0
Hover out of Ground Effect	0	2	0	4	3	0	0	0	1
Low Level	0	0	0	0	0	0	0	0	0
Approach	0	0	0	1	0	0	1	0	0
Training Autorotation	0	0	0	0	0	0	0	0	0
Emergency Autorotation	0	0	0	0	0	0	2	0	0
Power Recovery	0	0	0	0	0	0	0	0	0
Crash	0	0	0	0	0	0	6	0	0
Contour	2	0	0	1	0	0	1	0	0
Go around/ TALS Abort	0	0	0	0	0	0	0	0	0
NAP OF EARTH	0	0	0	0	0	0	0	0	0
Descent	0	0	0	0	0	0	0	0	0
Aerobatics	0	0	0	0	0	0	0	0	0
Deceleration	0	0	0	0	0	0	0	0	0
Combat Maneuver	2	0	0	3	0	0	0	0	0
Static Engine Run	0	0	0	0	0	0	0	0	0
Taxi	0	0	0	0	0	0	0	0	0
Termination	0	0	0	0	0	0	0	0	0
Total Data	**4**	**2**	**0**	**12**	**3**	**0**	**12**	**1**	**1**

Table E-13 – Phase of Operation, UH-1_T

UH-1_T	P-1	P-2	P-3	E-1	E-2	E-3	T-1	T-2	T-3
No. of Records	104	104	104	104	104	104	104	104	104
No. of Blank Records	97	104	104	25	93	103	14	65	98
No. of Records with Data	7	0	0	79	11	1	90	39	6
Phase Designators									
Climb at Take-off	0	0	0	6	0	0	0	0	0
Takeoff	2	0	0	8	0	0	2	0	0
Cruise	1	0	0	20	0	0	1	0	0
Turning	0	0	0	0	1	0	0	4	3
Formation	0	0	0	0	0	0	0	0	0
Landing Aircraft	1	0	0	17	1	0	53	0	0
Hover in Ground Effect	0	0	0	7	0	0	5	0	0
Hover out of Ground Effect	0	0	0	4	0	0	1	0	0
Low Level	0	0	0	6	1	0	5	1	2
Approach	1	0	0	5	0	0	2	0	0
Training Autorotation	0	0	0	1	6	0	1	6	1
Emergency Autorotation	1	0	0	0	2	0	4	25	0
Power Recovery	0	0	0	0	0	0	0	0	0
Crash	0	0	0	0	0	0	2	0	0
Contour	0	0	0	1	0	0	1	0	0
Go around/ TALS Abort	0	0	0	2	0	0	0	0	0
NAP OF EARTH	0	0	0	1	0	0	1	0	0
Descent	1	0	0	1	0	0	8	0	0
Aerobatics	0	0	0	0	0	0	3	0	0
Deceleration	0	0	0	0	0	1	0	3	0
Combat Maneuver	0	0	0	0	0	0	0	0	0
Static Engine Run	0	0	0	0	0	0	0	0	0
Taxi	0	0	0	0	0	0	0	0	0
Termination	0	0	0	0	0	0	1	0	0
Total Data	**7**	**0**	**0**	**79**	**11**	**1**	**90**	**39**	**6**

Table E-14 – Phase of Operation, UH-1_IT&TA

UH-1_IT&TA									
Records	52	52	52	52	52	52	52	52	52
Blank	52	52	52	19	46	52	7	36	52
Data	0	0	0	33	6	0	45	16	0
Climb at Take-off	0	0	0	3	0	0	0	0	0
Takeoff	0	0	0	2	0	0	1	0	0
Cruise	0	0	0	6	0	0	4	0	0
Turning	0	0	0	0	4	0	0	9	0
Formation	0	0	0	0	0	0	0	0	0
Landing Aircraft	0	0	0	4	1	0	16	1	0
Hover in Ground Effect	0	0	0	3	0	0	2	0	0
Hover out of Ground Effect	0	0	0	2	0	0	0	0	0
Low Level	0	0	0	6	0	0	12	0	0
Approach	0	0	0	2	0	0	2	0	0
Training Autorotation	0	0	0	0	1	0	0	1	0
Emergency Autorotation	0	0	0	0	0	0	0	5	0
Power Recovery	0	0	0	0	0	0	0	0	0
Crash	0	0	0	0	0	0	2	0	0
Contour	0	0	0	1	0	0	1	0	0
Go around/ TALS Abort	0	0	0	2	0	0	2	0	0
NAP OF EARTH	0	0	0	1	0	0	0	0	0
Descent	0	0	0	1	0	0	3	0	0
Aerobatics	0	0	0	0	0	0	0	0	0
Deceleration	0	0	0	0	0	0	0	0	0
Combat Maneuver	0	0	0	0	0	0	0	0	0
Static Engine Run	0	0	0	0	0	0	0	0	0
Taxi	0	0	0	0	0	0	0	0	0
Termination	0	0	0	0	0	0	0	0	0
Total Data	**0**	**0**	**0**	**33**	**6**	**0**	**45**	**16**	**0**

Table E-15 – Phase of Operation, UH-60_T

UH-60_T									
Records	38	38	38	38	38	38	38	38	38
Blank	27	37	38	5	32	38	3	30	38
Data	11	1	0	33	6	0	35	8	0
Climb at Take-off	0	0	0	2	0	0	1	0	0
Takeoff	1	0	0	1	0	0	0	0	0
Cruise	4	1	0	3	0	0	1	0	0
Turning	1	0	0	0	1	0	0	2	0
Formation	0	0	0	0	2	0	0	0	0
Landing Aircraft	1	0	0	6	2	0	15	0	0
Hover in Ground Effect	1	0	0	2	0	0	0	0	0
Hover out of Ground Effect	0	0	0	1	0	0	0	0	0
Low Level	2	0	0	5	0	0	1	0	0
Approach	1	0	0	7	0	0	2	0	0
Training Autorotation	0	0	0	0	0	0	0	0	0
Emergency Autorotation	0	0	0	0	1	0	1	6	0
Power Recovery	0	0	0	0	0	0	0	0	0
Crash	0	0	0	0	0	0	8	0	0
Contour	0	0	0	0	0	0	1	0	0
Go around/ TALS Abort	0	0	0	1	0	0	0	0	0
NAP OF EARTH	0	0	0	0	0	0	0	0	0
Descent	0	0	0	3	0	0	4	0	0
Aerobatics	0	0	0	1	0	0	0	0	0
Deceleration	0	0	0	0	0	0	0	0	0
Combat Maneuver	0	0	0	0	0	0	0	0	0
Static Engine Run	0	0	0	0	0	0	0	0	0
Taxi	0	0	0	1	0	0	1	0	0
Termination	0	0	0	0	0	0	0	0	0
Total Data	**11**	**1**	**0**	**33**	**6**	**0**	**35**	**8**	**0**

Table E-16 – Phase of Operation, UH-60_IT&TA

UH-60_IT&TA									
Records	25	25	25	25	25	25	25	25	25
Blank	20	24	25	4	21	25	6	20	25
Data	5	1	0	21	4	0	19	5	0
Climb at Take-off	0	0	0	1	0	0	0	0	0
Takeoff	0	0	0	0	0	0	0	0	0
Cruise	1	0	0	6	0	0	1	0	0
Turning	0	0	0	0	0	0	0	1	0
Formation	0	1	0	1	4	0	0	0	0
Landing Aircraft	1	0	0	1	0	0	5	0	0
Hover in Ground Effect	0	0	0	0	0	0	0	0	0
Hover out of Ground Effect	0	0	0	0	0	0	1	0	0
Low Level	2	0	0	5	0	0	0	0	0
Approach	0	0	0	1	0	0	2	0	0
Training Autorotation	0	0	0	0	0	0	0	0	0
Emergency Autorotation	0	0	0	0	0	0	0	3	0
Power Recovery	0	0	0	0	0	0	0	0	0
Crash	0	0	0	0	0	0	6	0	0
Contour	1	0	0	3	0	0	1	0	0
Go around/ TALS Abort	0	0	0	1	0	0	0	0	0
NOE	0	0	0	0	0	0	0	0	0
Descent	0	0	0	2	0	0	3	0	0
Aerobatics	0	0	0	0	0	0	0	0	0
Deceleration	0	0	0	0	0	0	0	1	0
Combat Maneuver	0	0	0	0	0	0	0	0	0
Static Engine Run	0	0	0	0	0	0	0	0	0
Taxi	0	0	0	0	0	0	0	0	0
Termination	0	0	0	0	0	0	0	0	0
Total Data	**5**	**1**	**0**	**21**	**4**	**0**	**19**	**5**	**0**

Appendix F – Resultant Impact Severity Plots

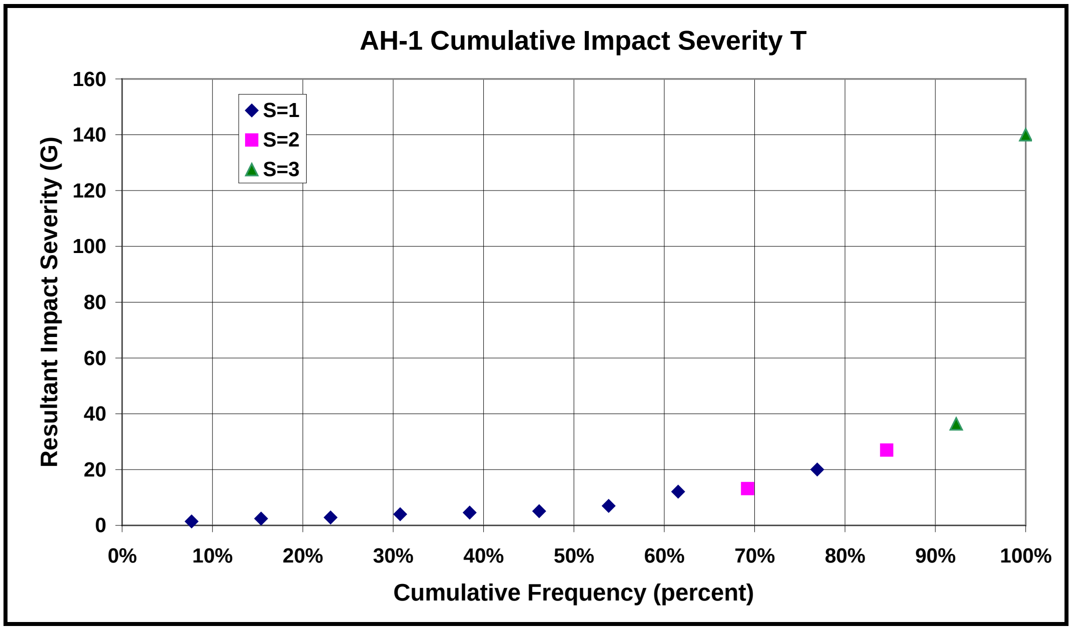

Figure F-1 – AH-1 Cumulative Impact Severity (T)

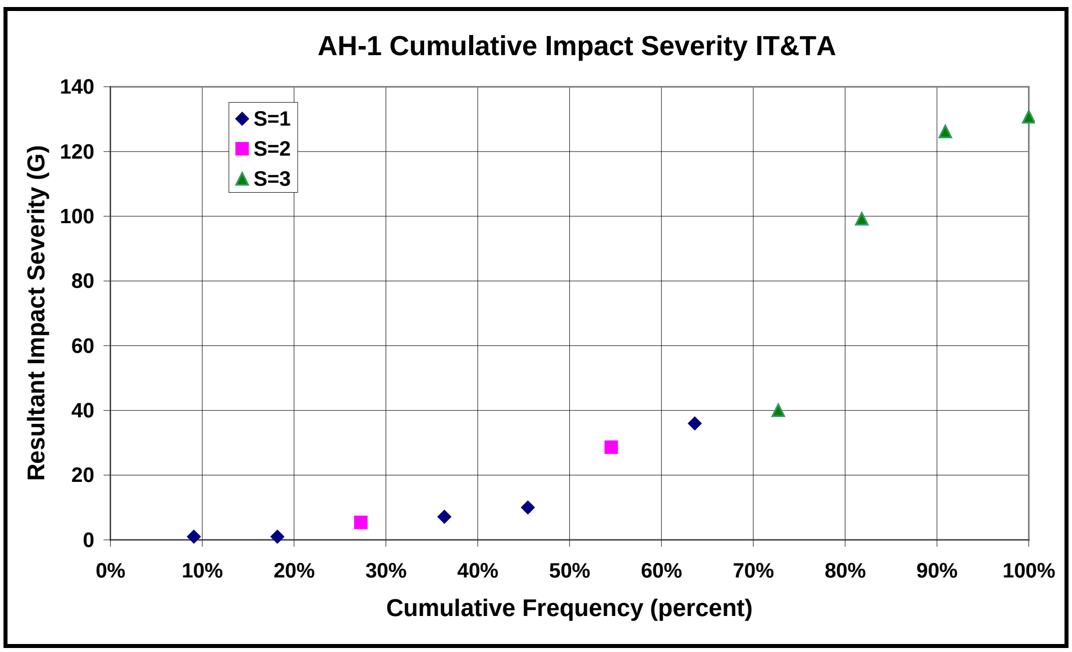

Figure F-2 – AH-1 Cumulative Impact Severity (IT&TA)

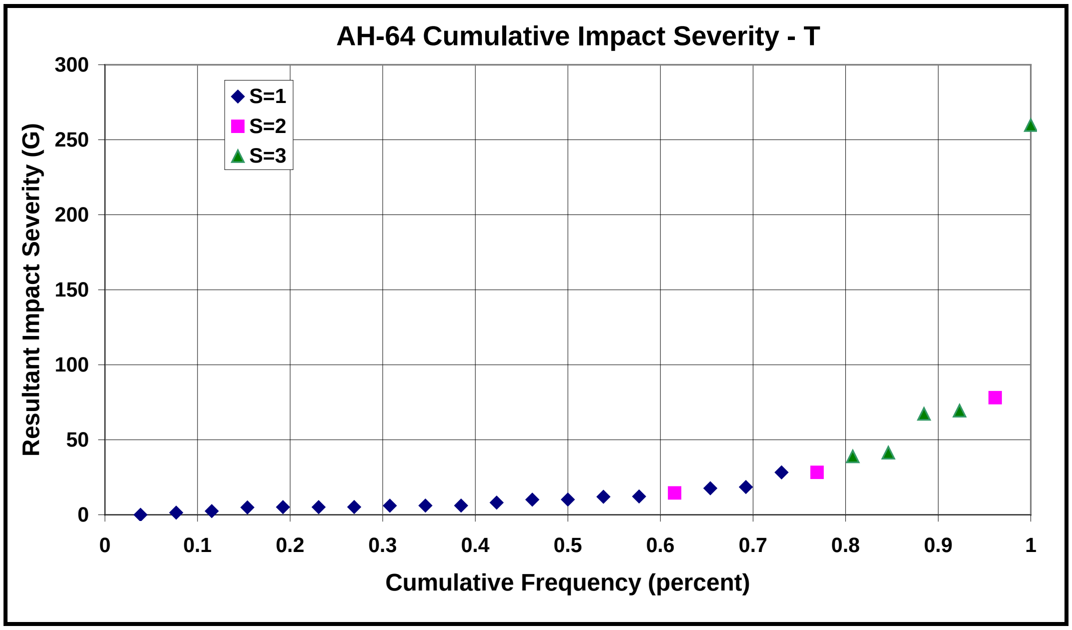

Figure F-3 – AH-64 Cumulative Impact Severity (T)

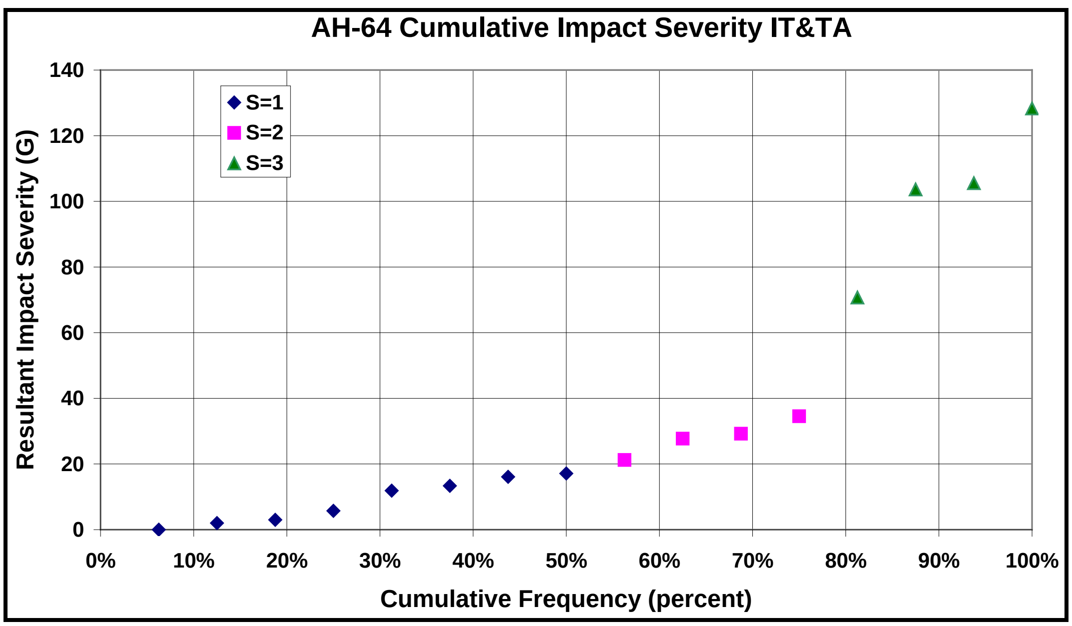

Figure F-4 – AH-64 Cumulative Impact Severity (IT&TA)

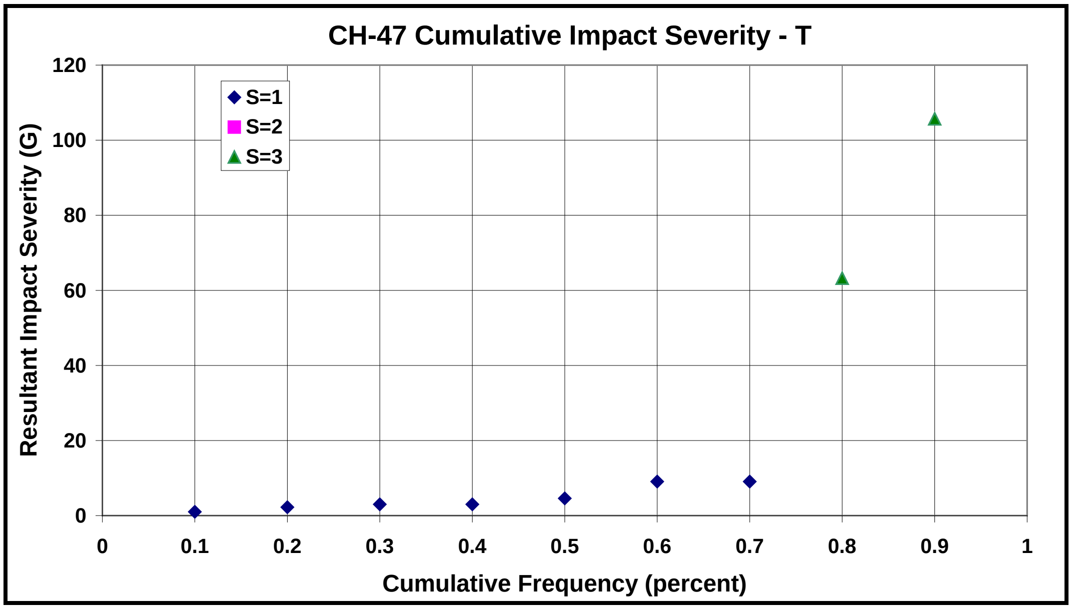

Figure F-5 – CH-47 Cumulative Impact Severity (T)

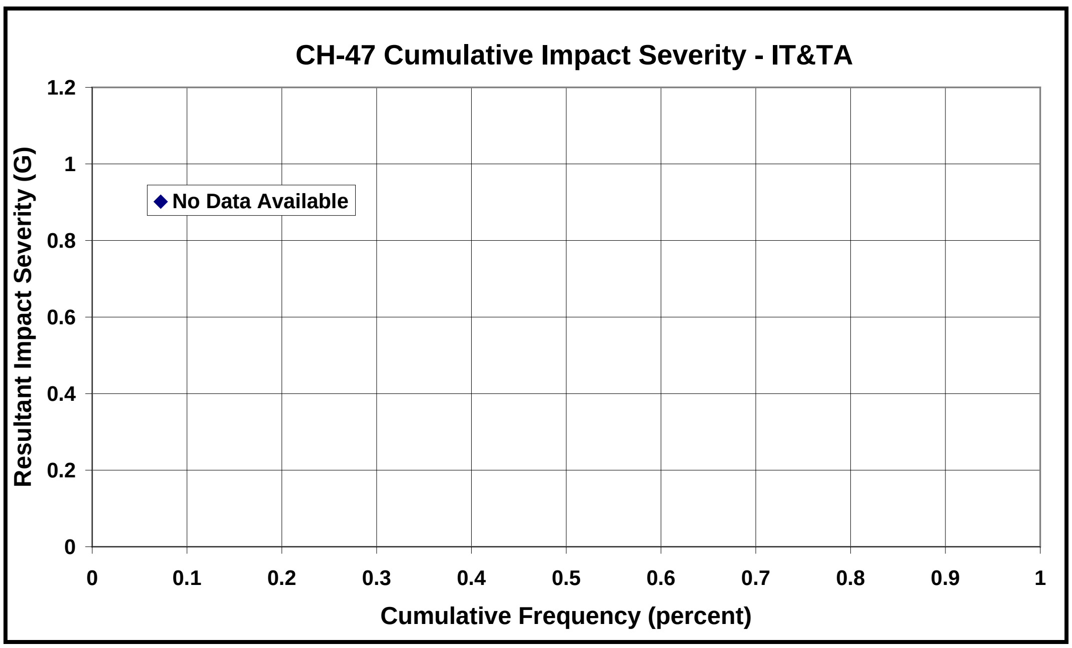

Figure F-6 – CH-47 Cumulative Impact Severity (IT&TA)

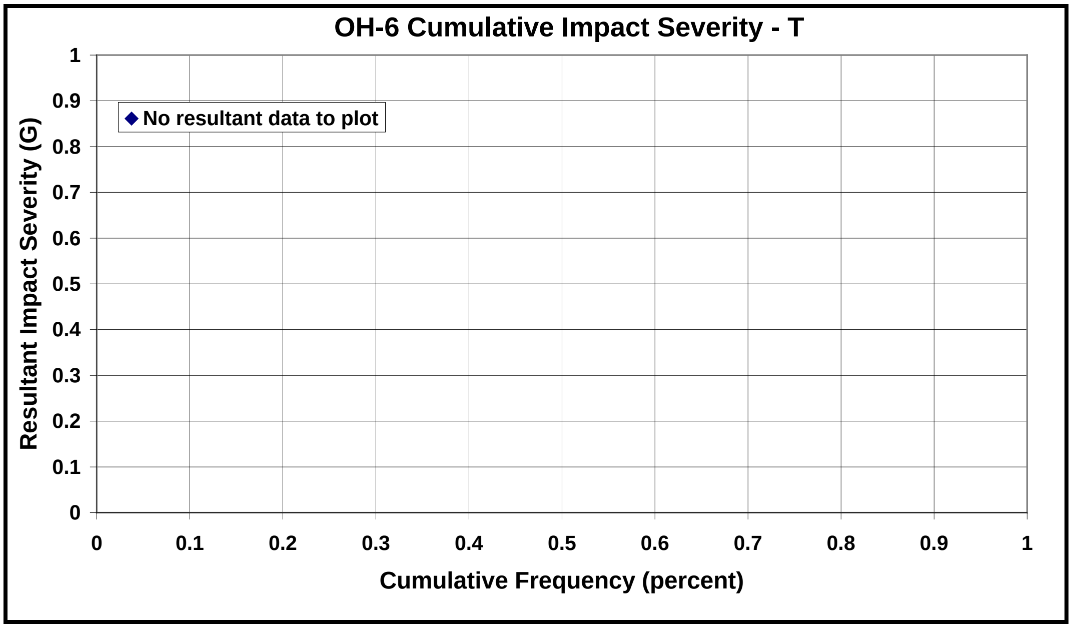

Figure F-7 – OH-6 Cumulative Impact Severity (T)

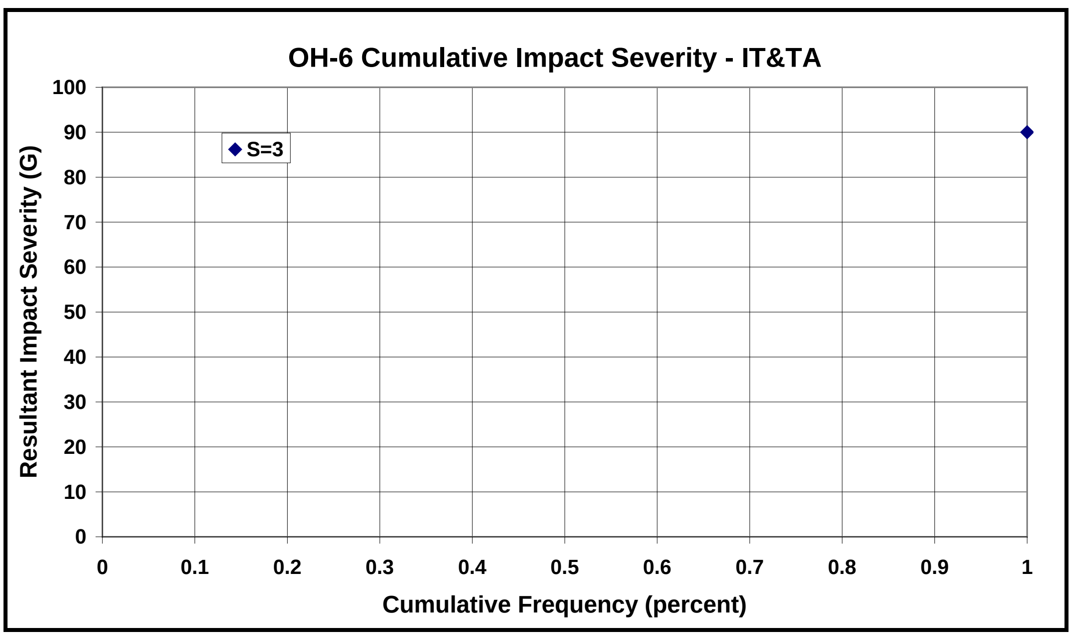

Figure F-8 – OH-6 Cumulative Impact Severity (IT&TA)

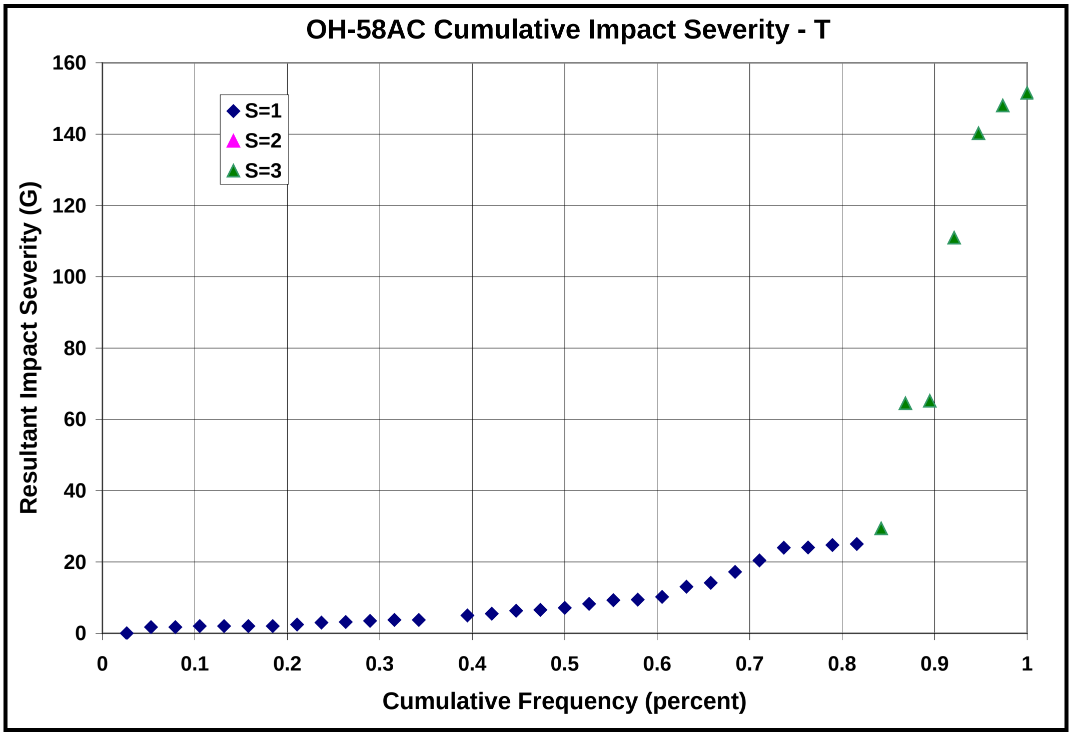

Figure F-9 – OH-58AC Cumulative Impact Severity (T)

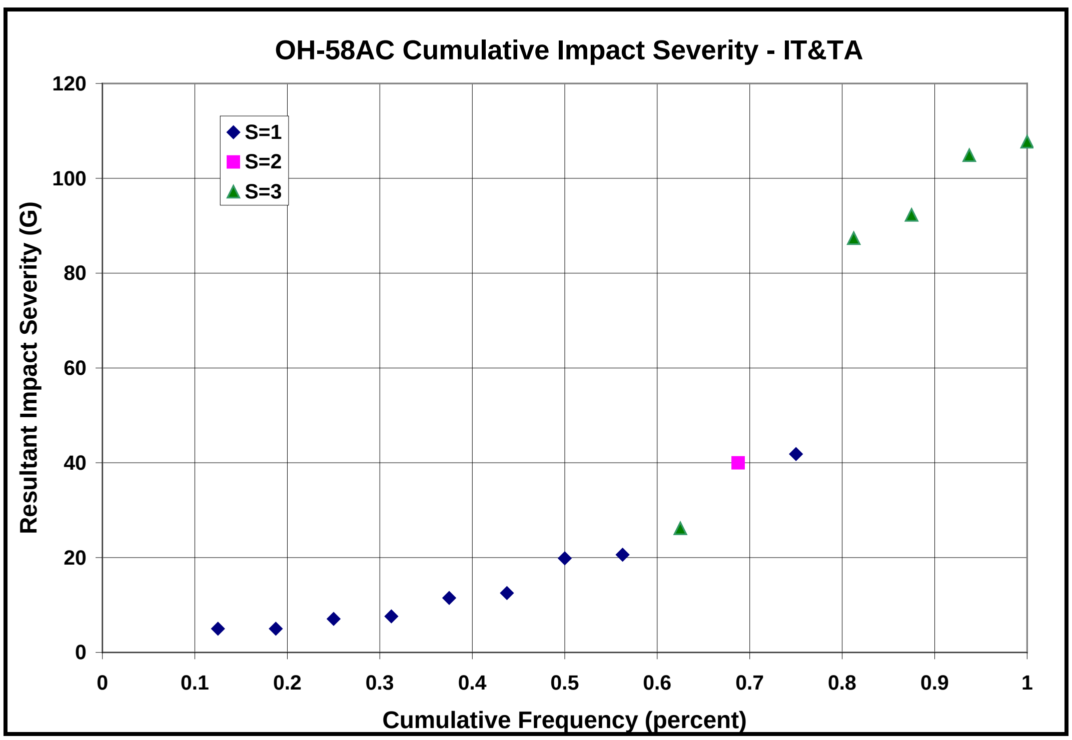

Figure F-10 – OH-58AC Cumulative Impact Severity (IT&TA)

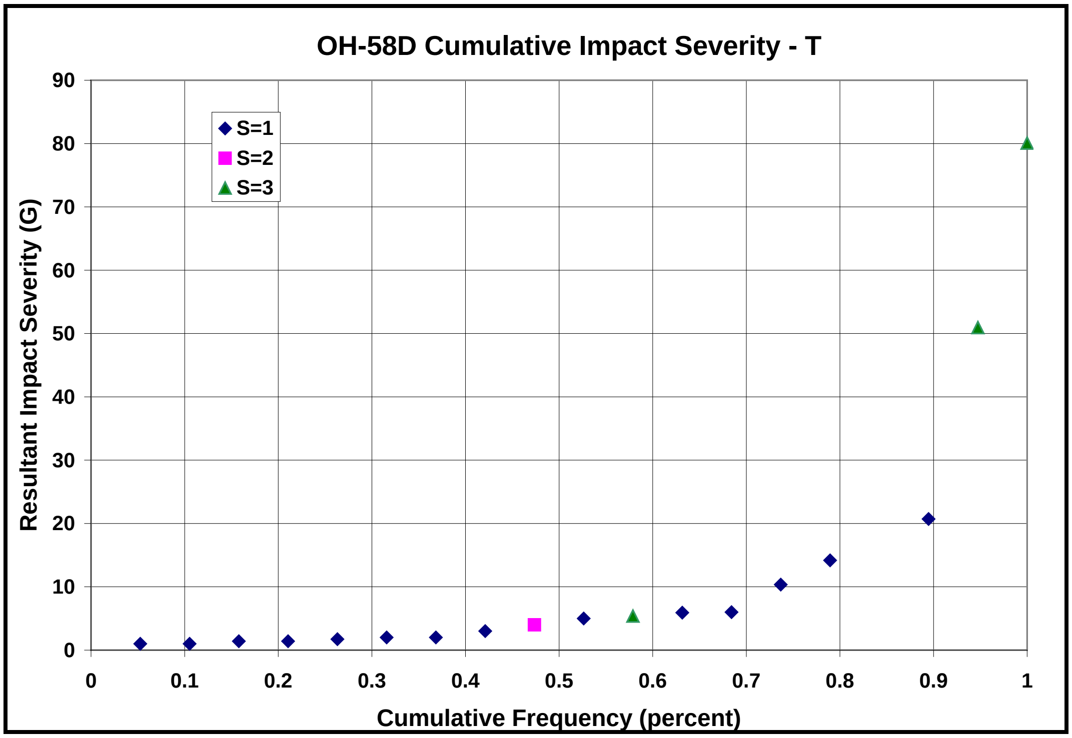

Figure F-11 – OH-58D Cumulative Impact Severity (T)

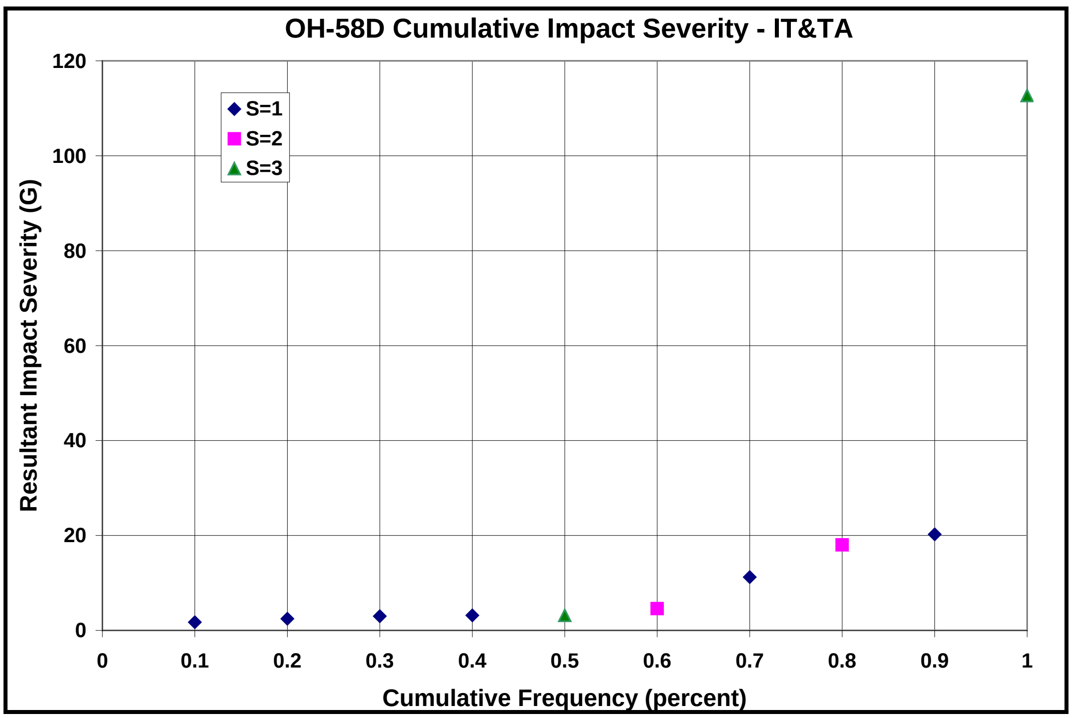

Figure F-12 – OH-58D Cumulative Impact Severity (IT&TA)

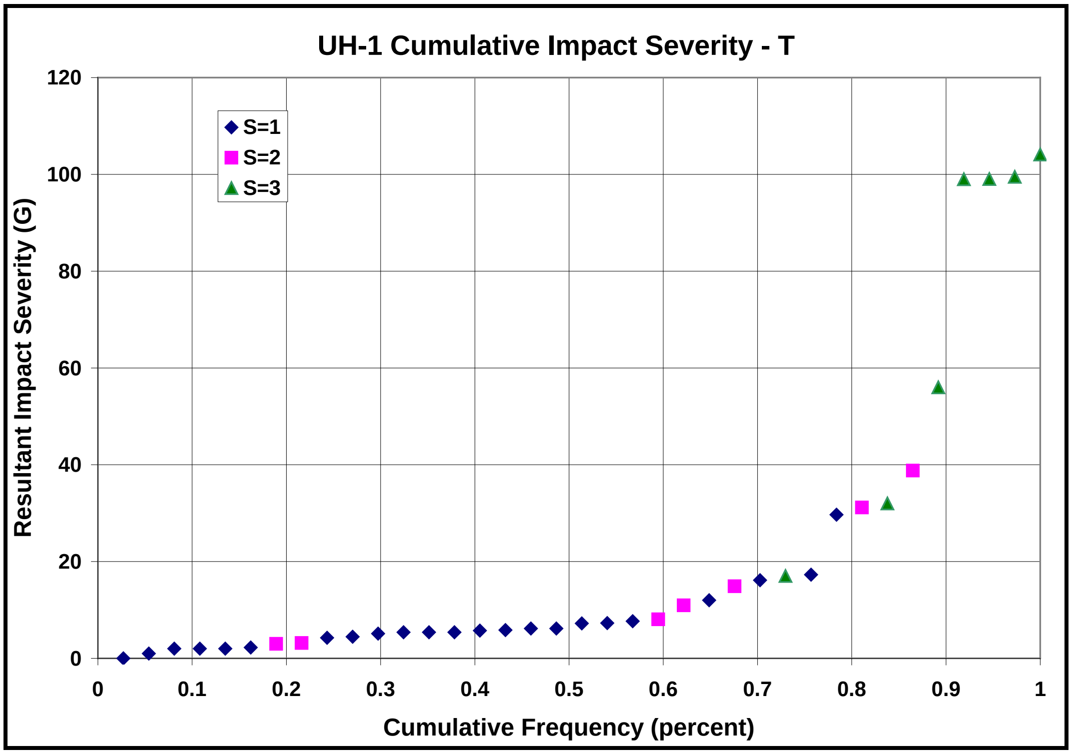

Figure F-13 – UH-1 Cumulative Impact Severity (T)

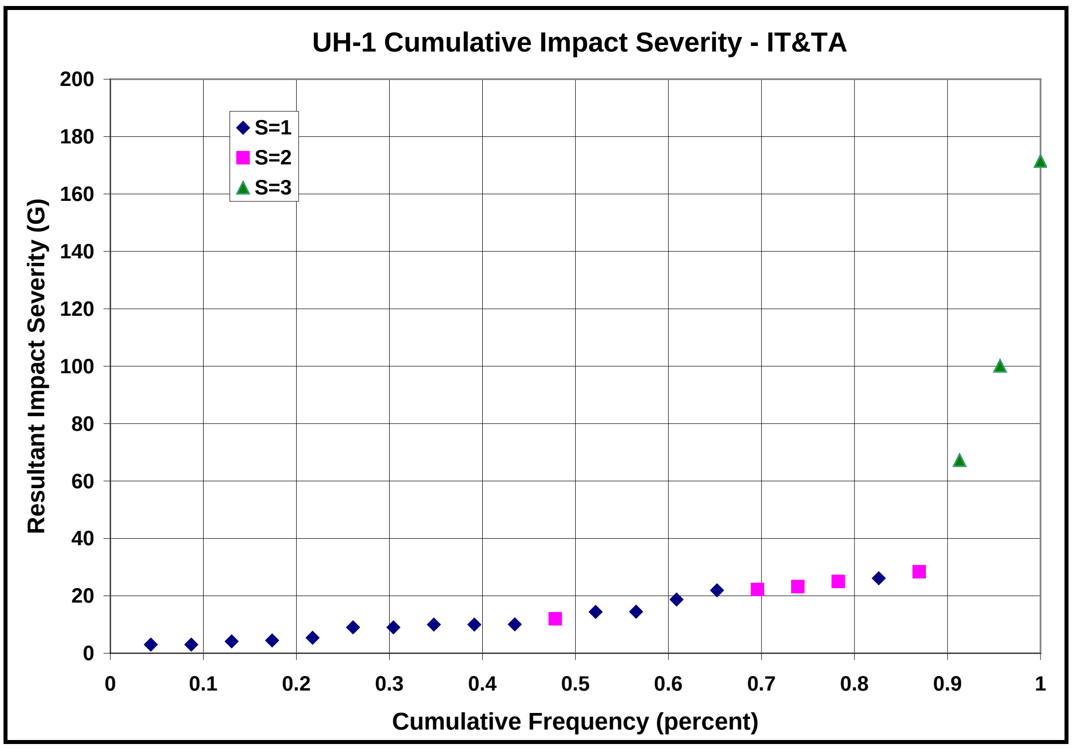

Figure F-14 – UH-1 Cumulative Impact Severity (IT&TA)

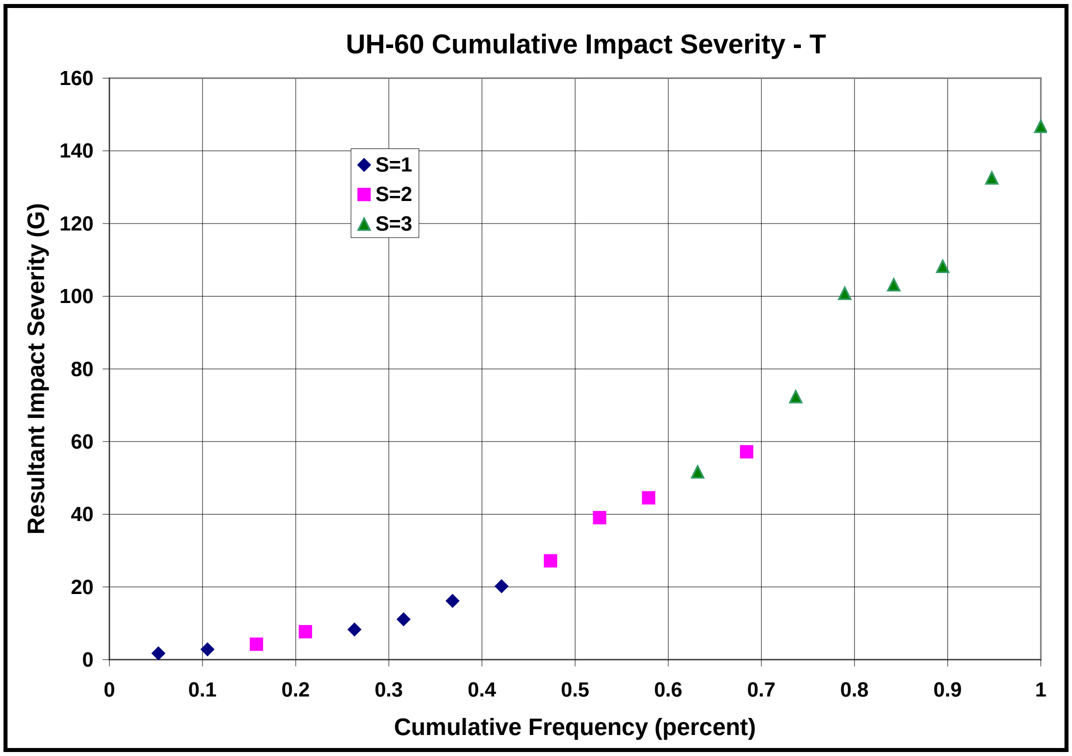

Figure F-15 – UH-60 Cumulative Impact Severity (T)

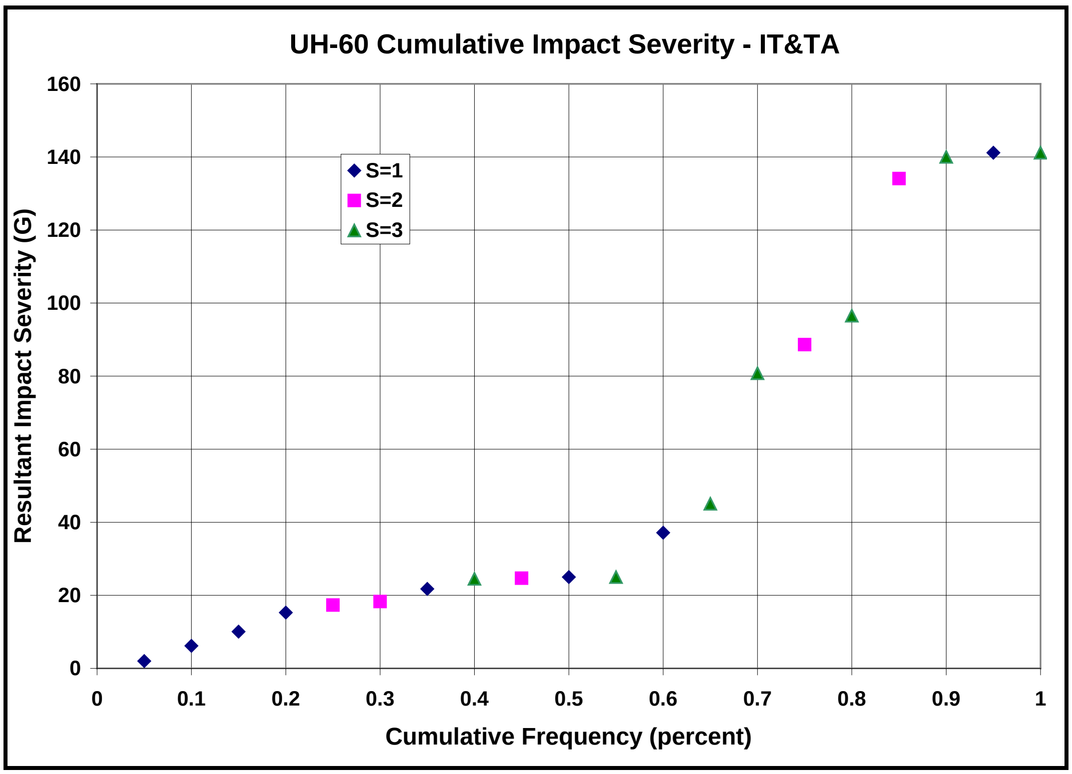

Figure F-16 – UH-60 Cumulative Impact Severity (IT&TA)

Appendix G – Airframe Damage Maps

G-1 – Attack Helicopters

G-2 – Cargo Helicopters

G-3 – Observation Helicopters

G-4 – Utility Helicopters

Appendix G – Airframe Damage Maps

G1 – Attack Helicopters

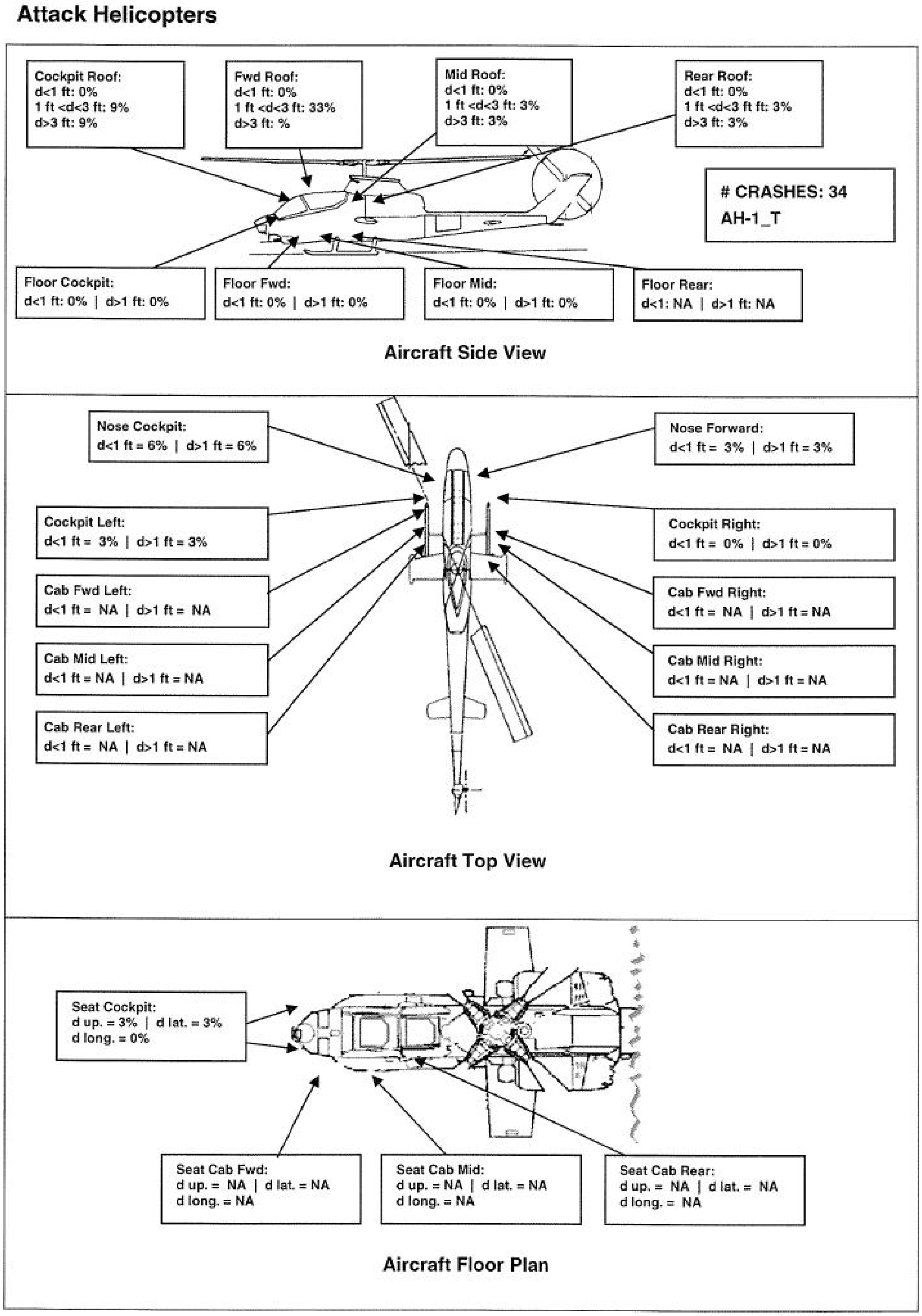

Figure G1-1 – Attack Helicopter Crash/Damage Percentages, AH-1_T

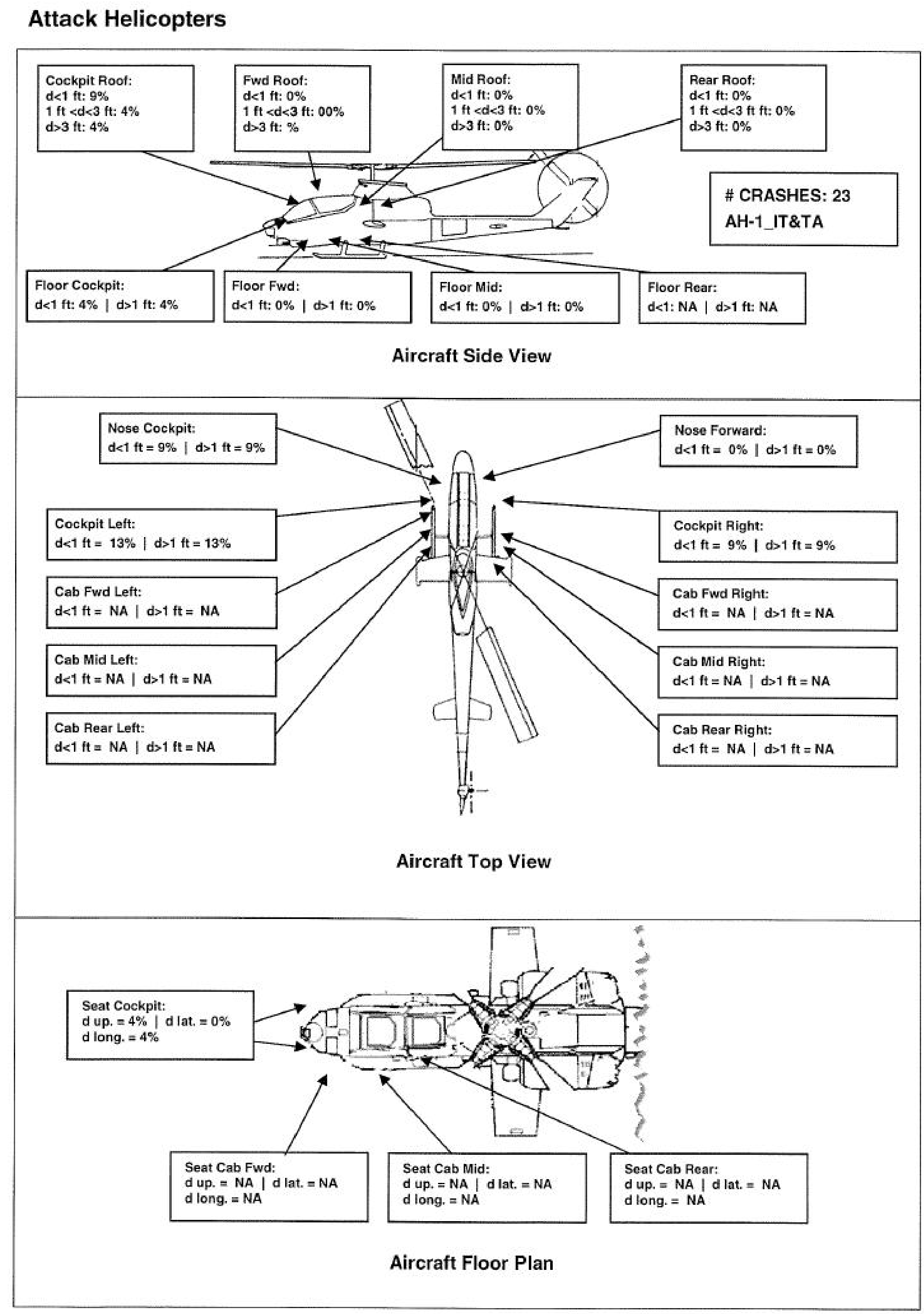

Figure G1-2 – Attack Helicopter Crash/Damage Percentages, AH-1_IT&TA

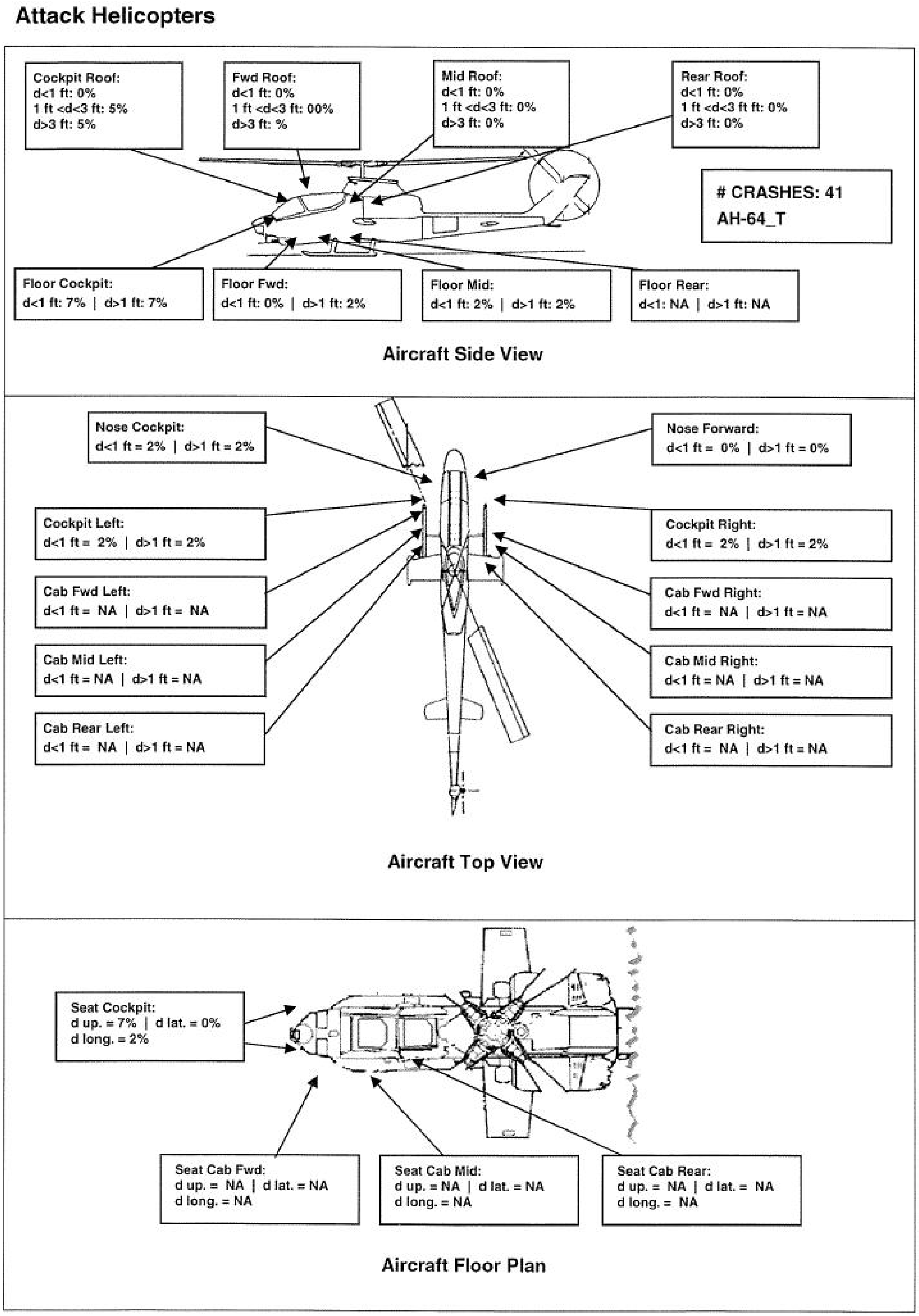

Figure G1-3 – Attack Helicopter Crash/Damage Percentages, AH-64_T

Attack Helicopters

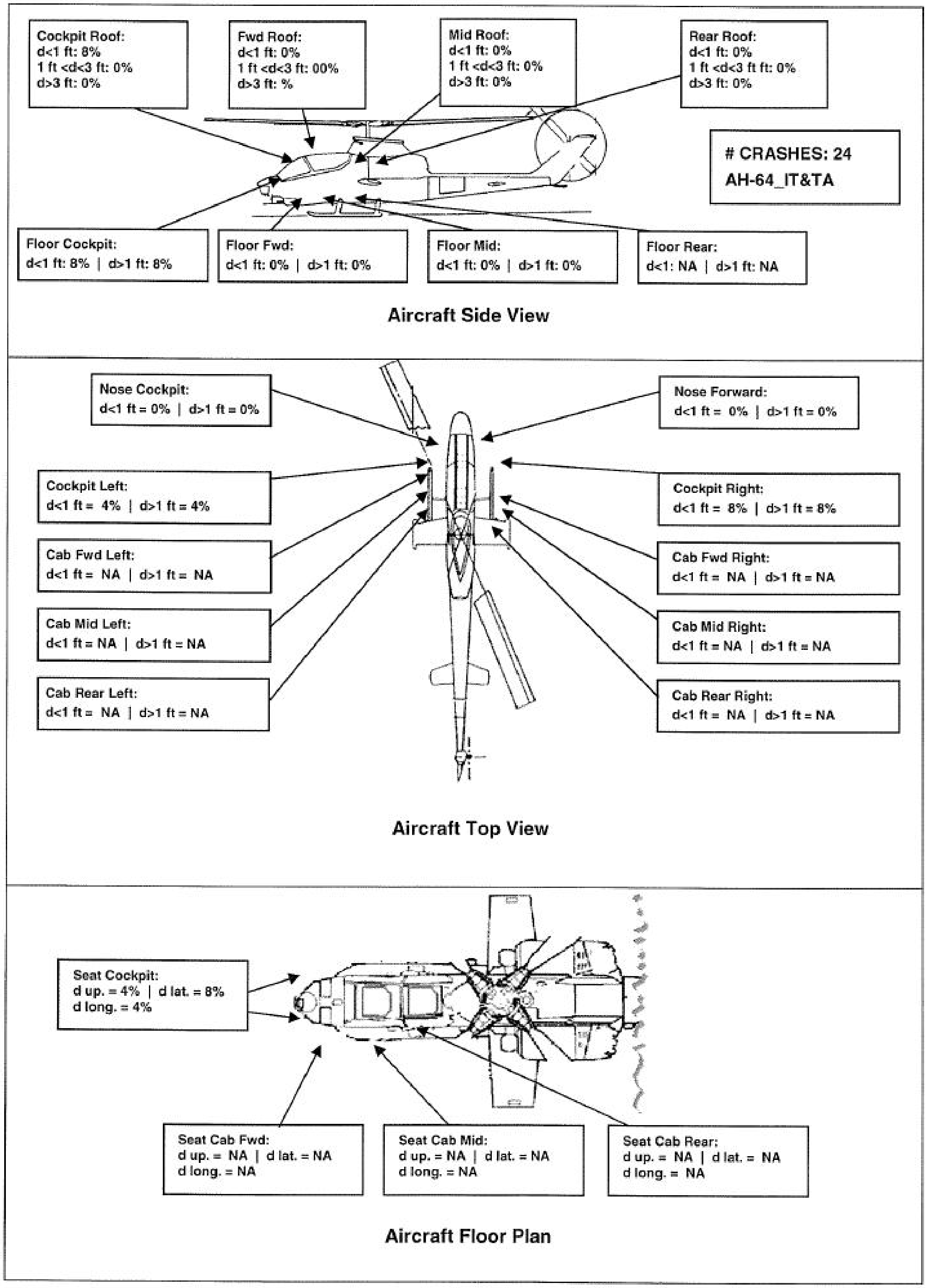

Figure G1-4 – Attack Helicopter Crash/Damage Percentages, AH-64_IT&TA

Appendix G – Airframe Damage Maps

G2 – Cargo Helicopters

Cargo Helicopters

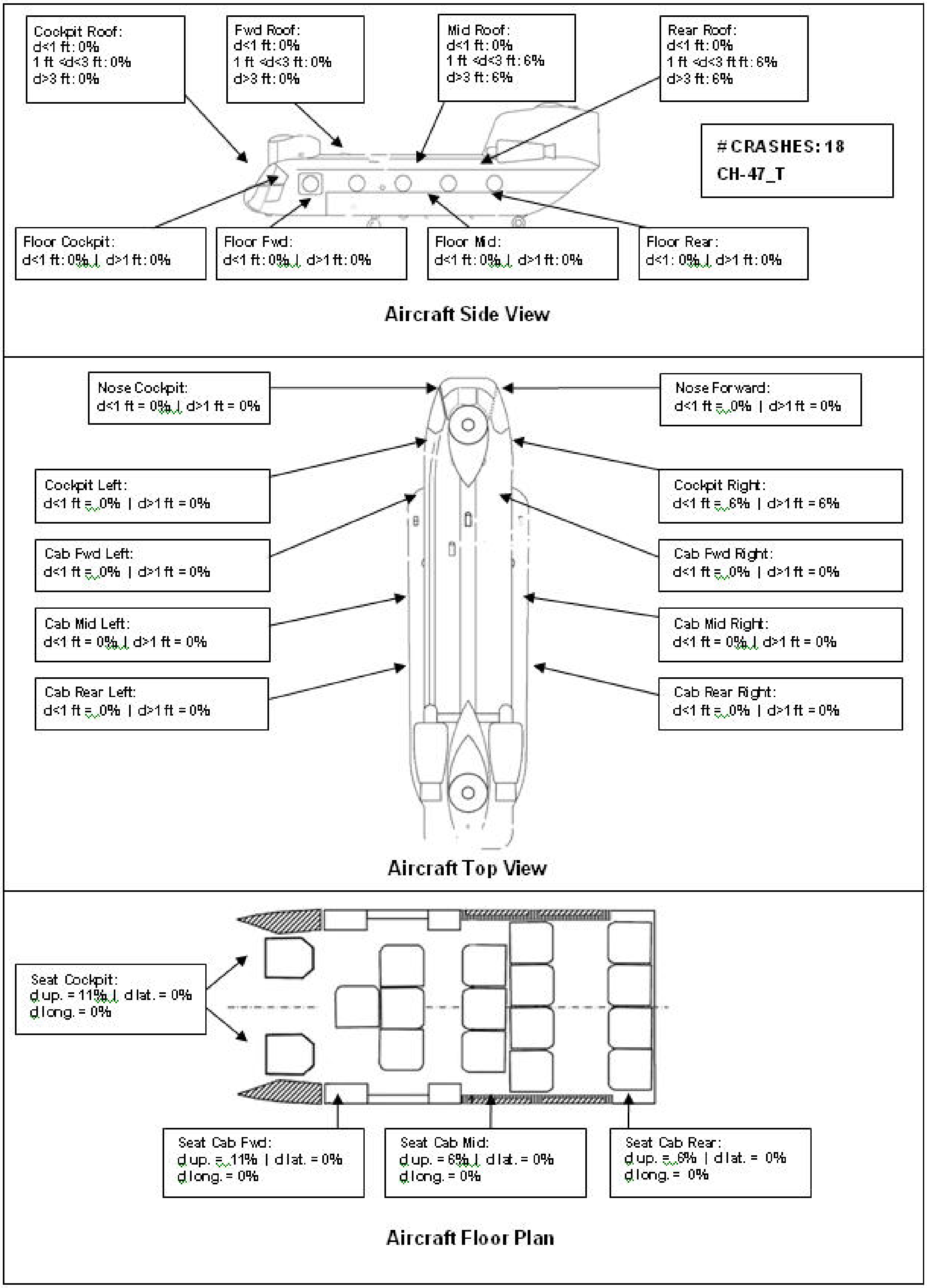

Figure G2-1 – Cargo Helicopter Crash/Damage Percentages, CH-47_T

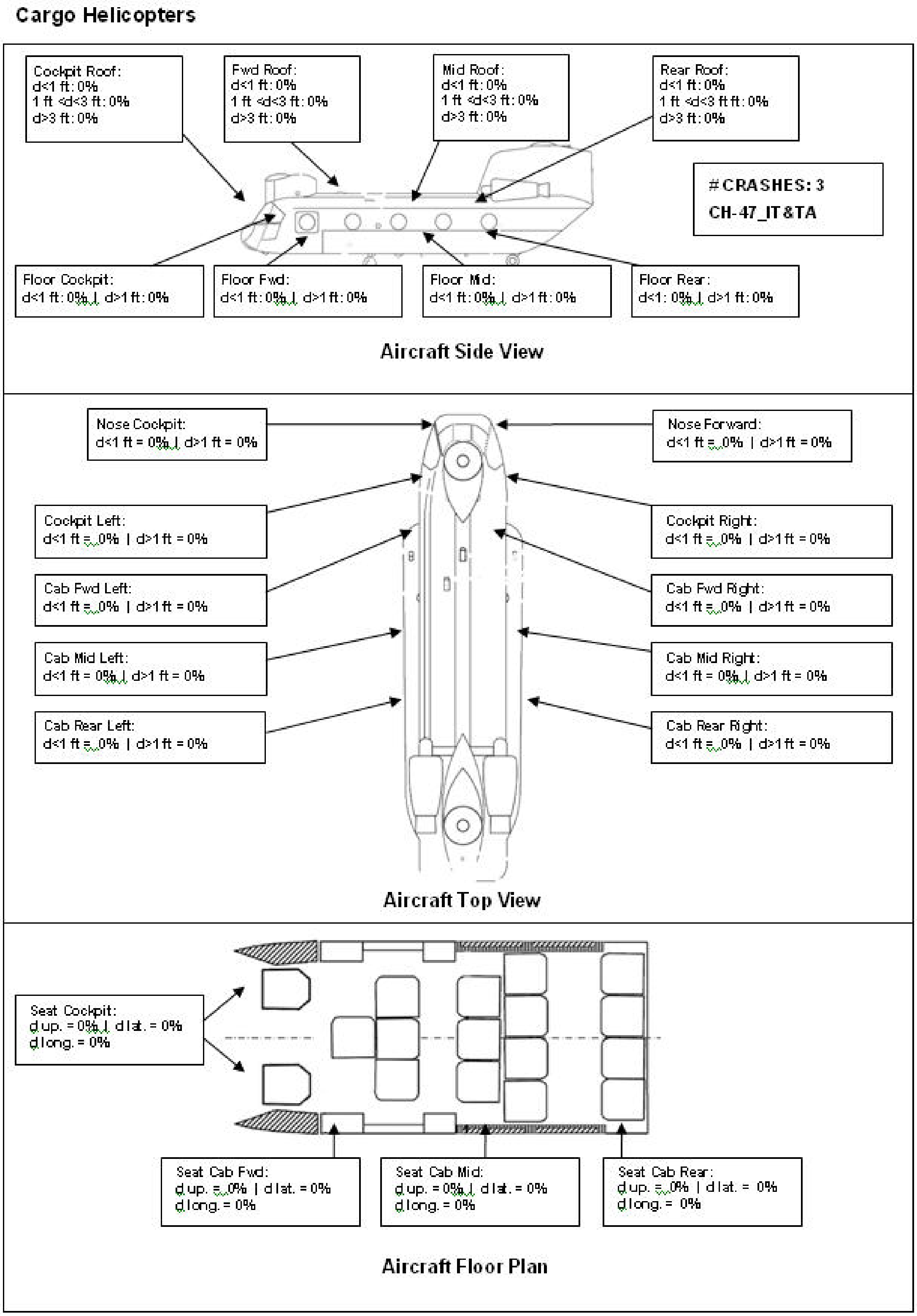

Figure G2-2 – Cargo Helicopter Crash/Damage Percentages, CH-47_IT&TA

Appendix G – Airframe Damage Maps

G3 – Observation Helicopters

Observation Helicopters

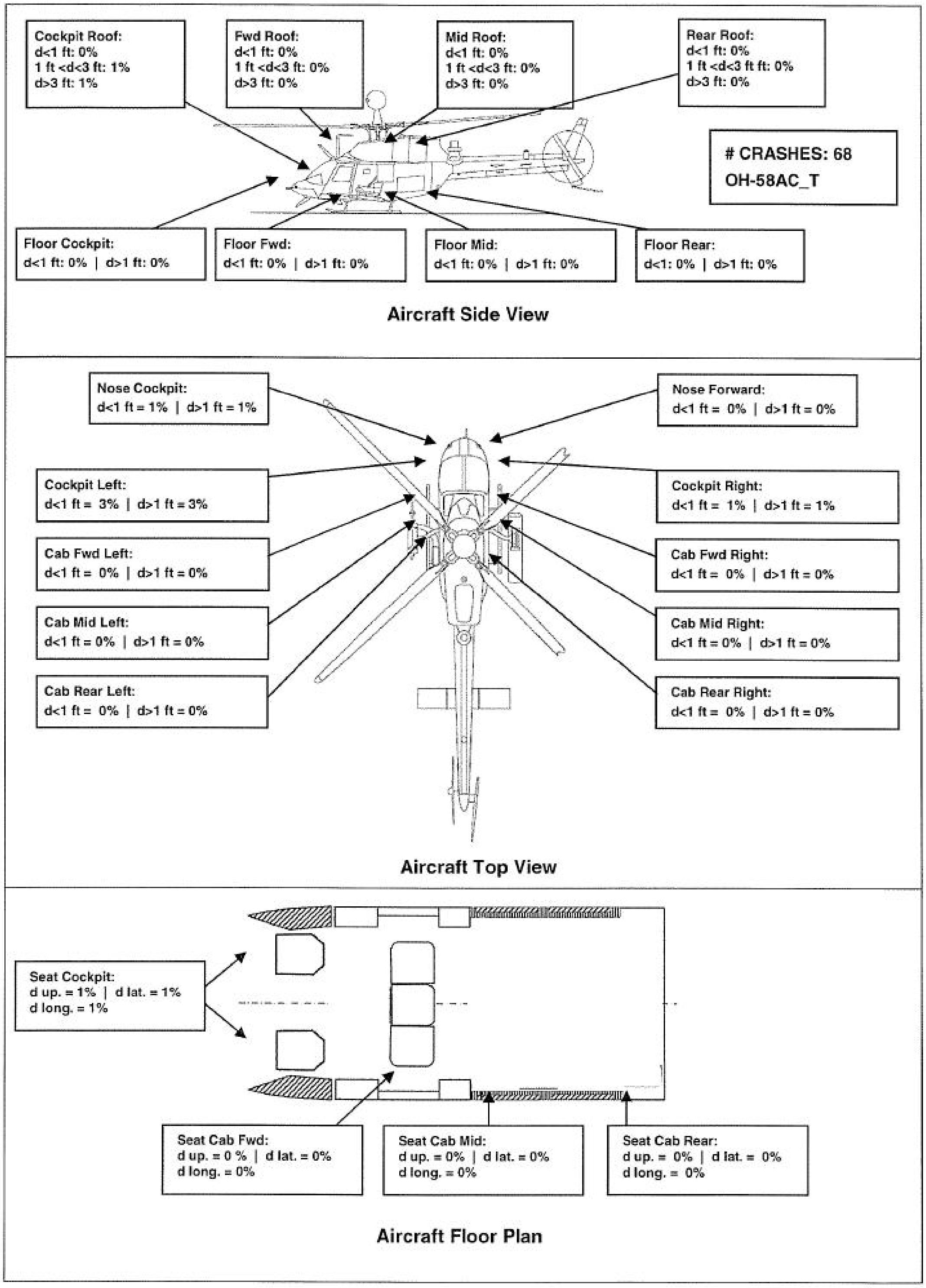

Figure G3-1 – Observation Helicopter Crash/Damage Percentages, OH-58AC_T

Observation Helicopters

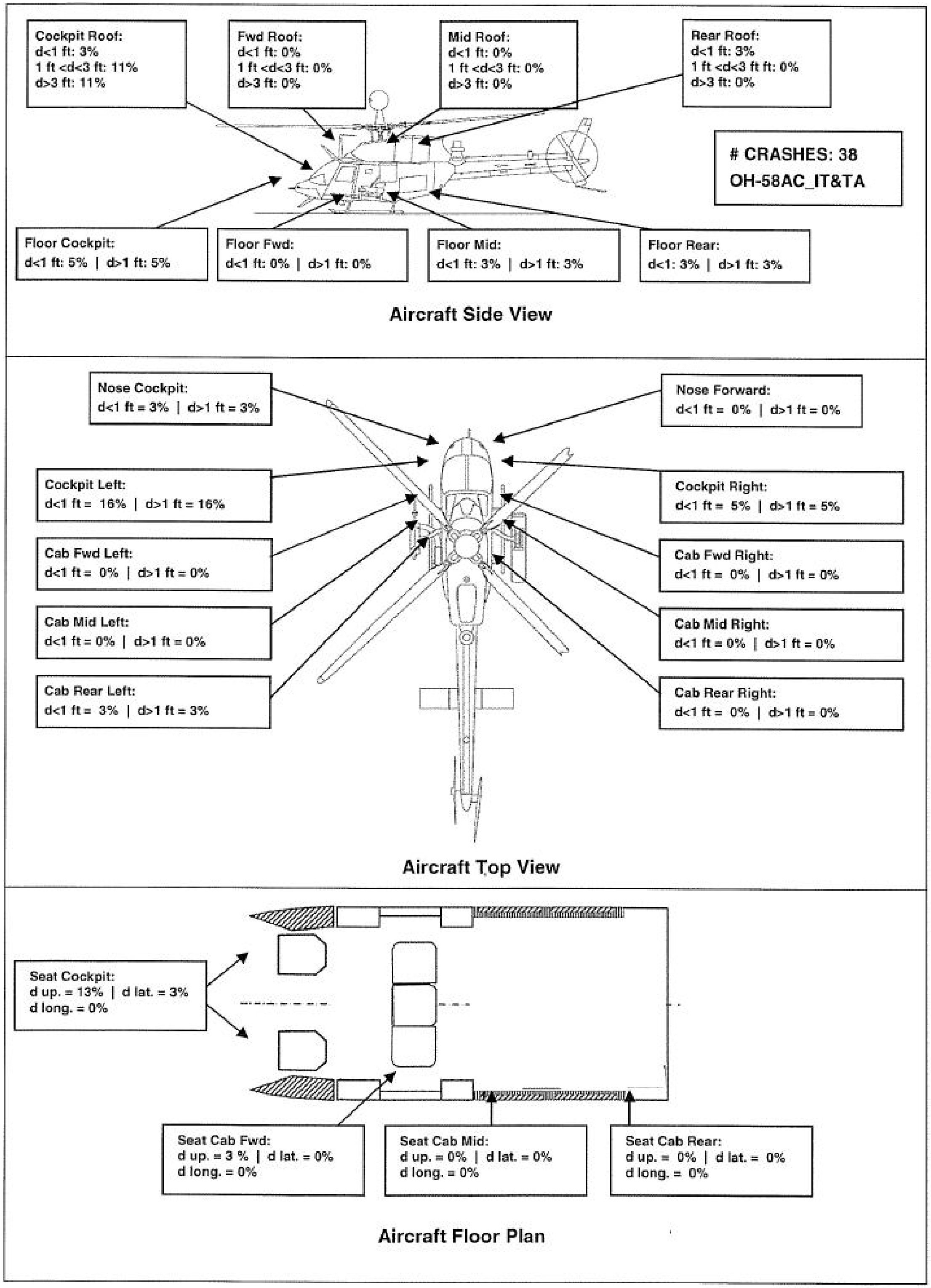

Figure G3-2 – Observation Helicopter Crash/Damage Percentages, OH-58AC_IT&TA

Observation Helicopters

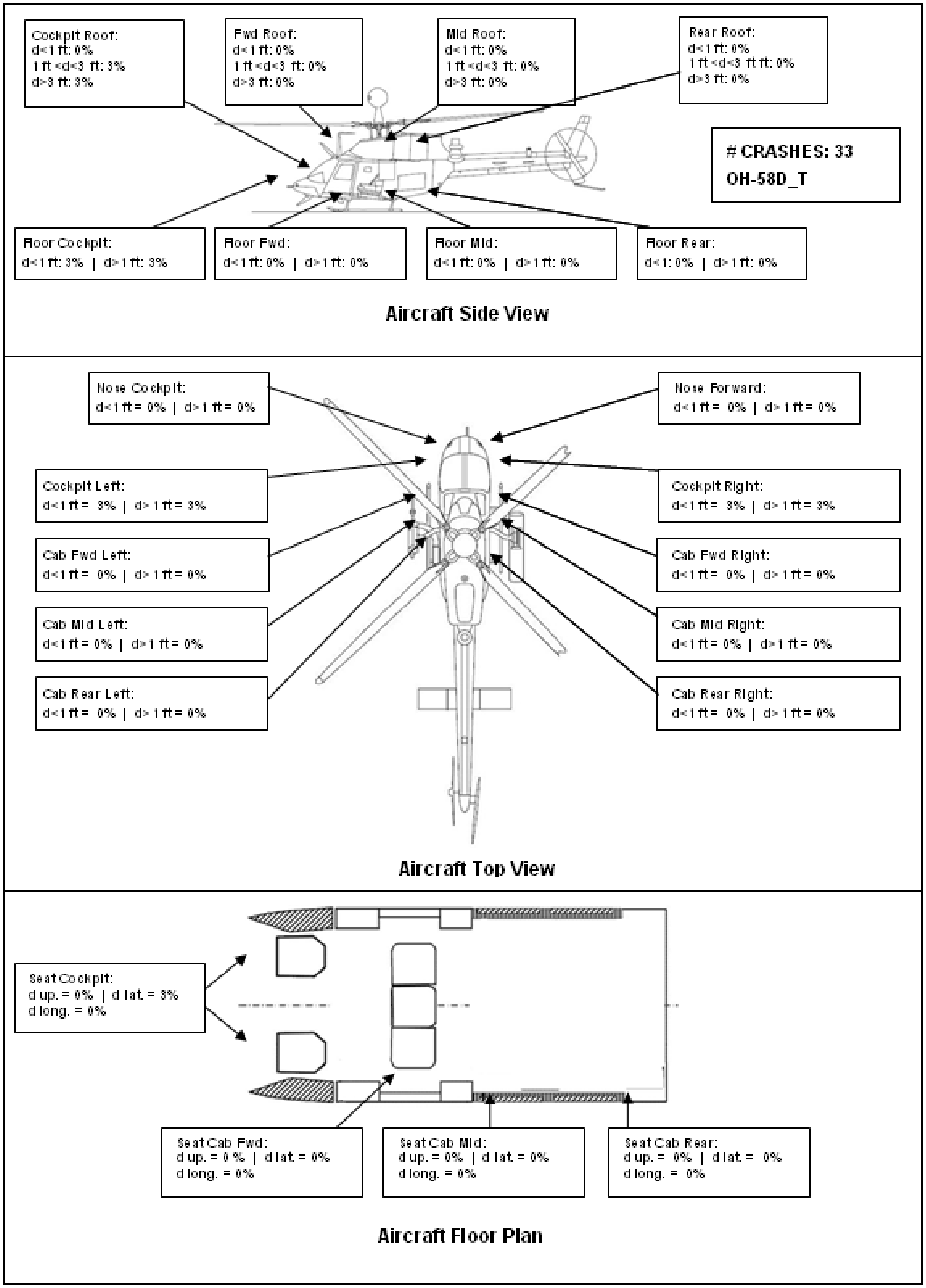

Figure G3-3 – Observation Helicopter Crash/Damage Percentages, OH-58D_T

Observation Helicopters

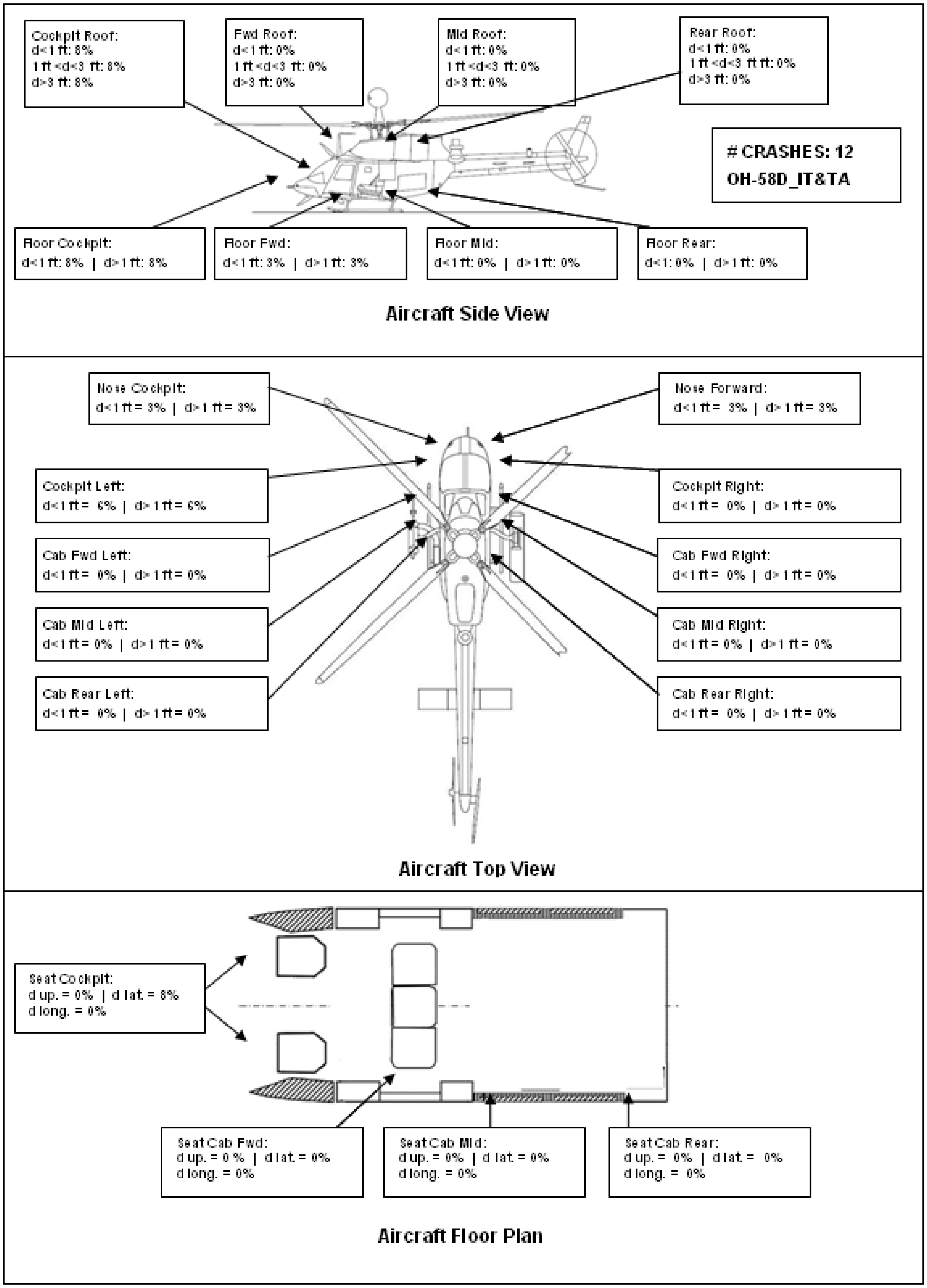

Figure G3-4 – Observation Helicopter Crash/Damage Percentages, OH-58D_IT&TA

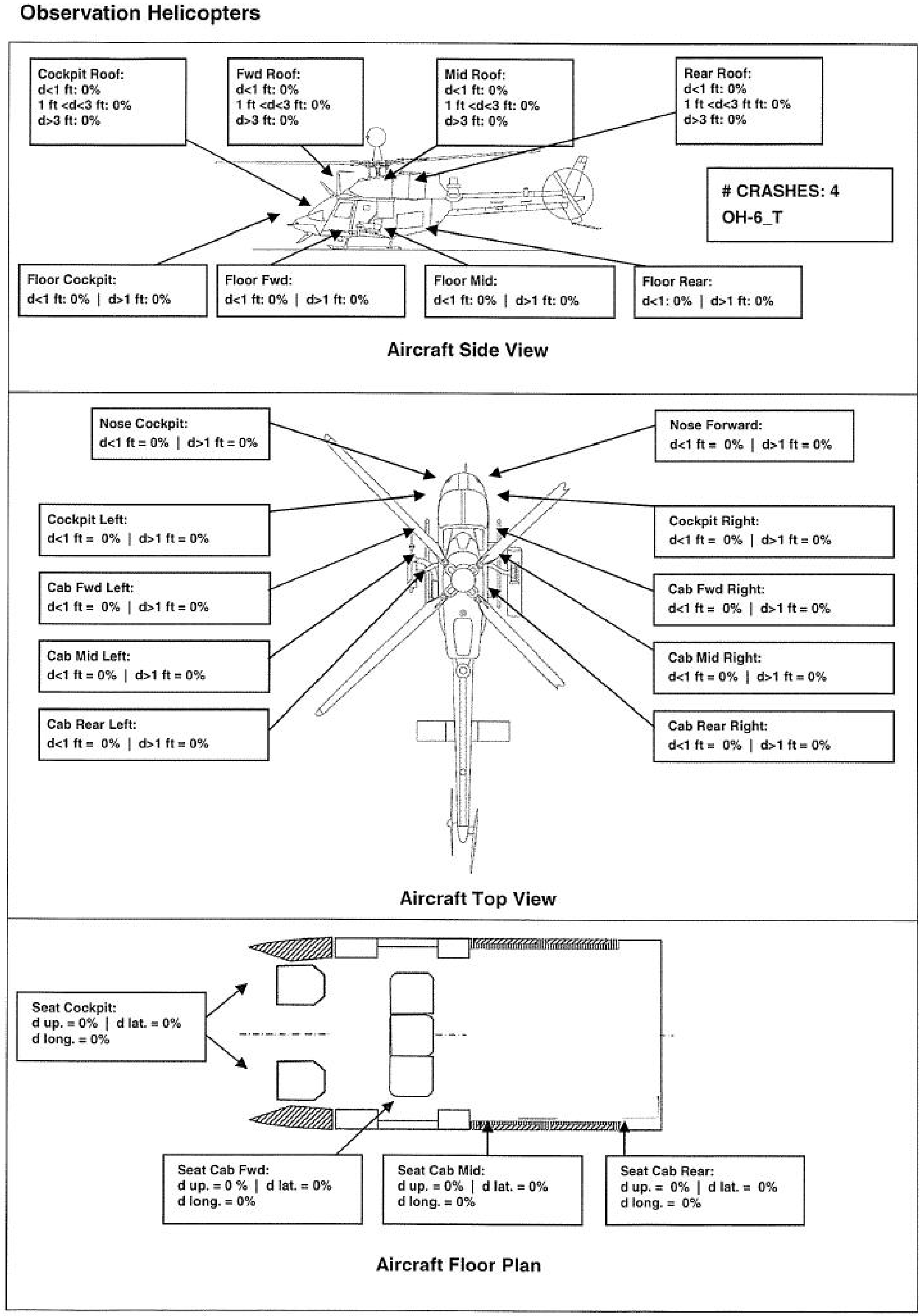

Figure G3-5 – Observation Helicopter Crash/Damage Percentages, OH-6_T

Observation Helicopters

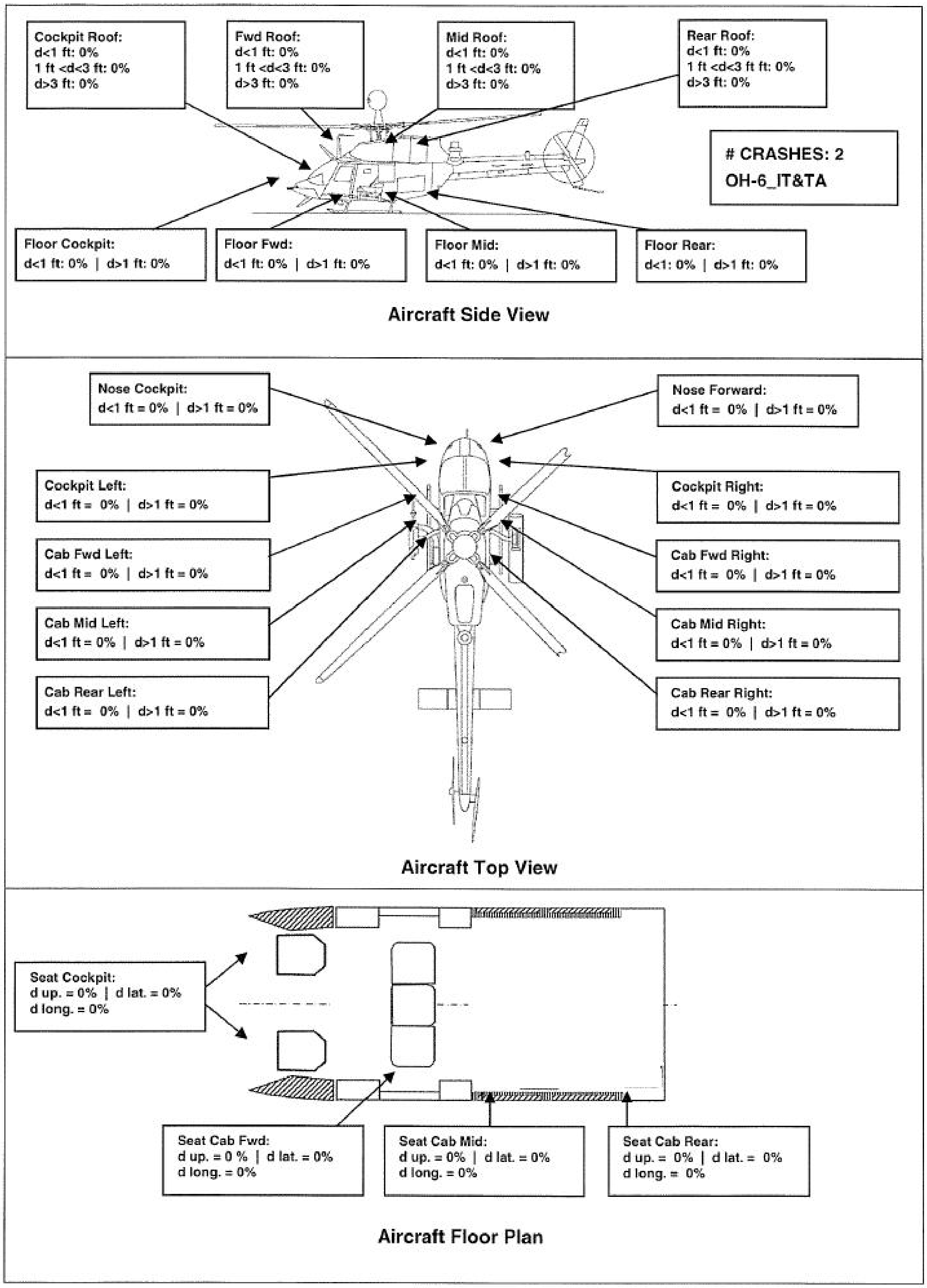

Figure G3-6 –Observation Helicopter Crash/Damage Percentages, OH-6_IT&TA

Appendix G – Airframe Damage Maps

G4 – Utility Helicopters

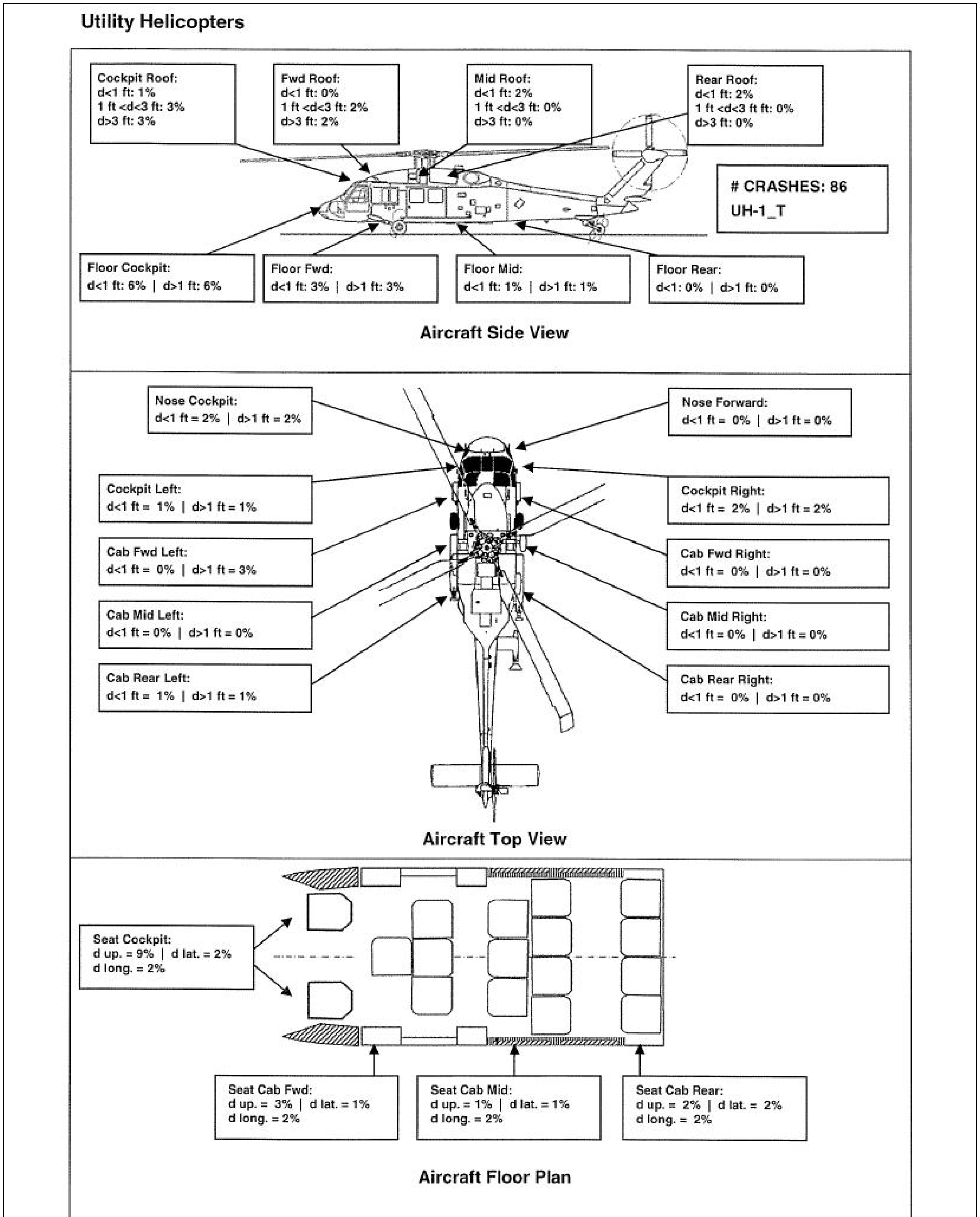

Figure G4-1 – Utility Helicopter Crash/Damage Percentages, UH-1_T

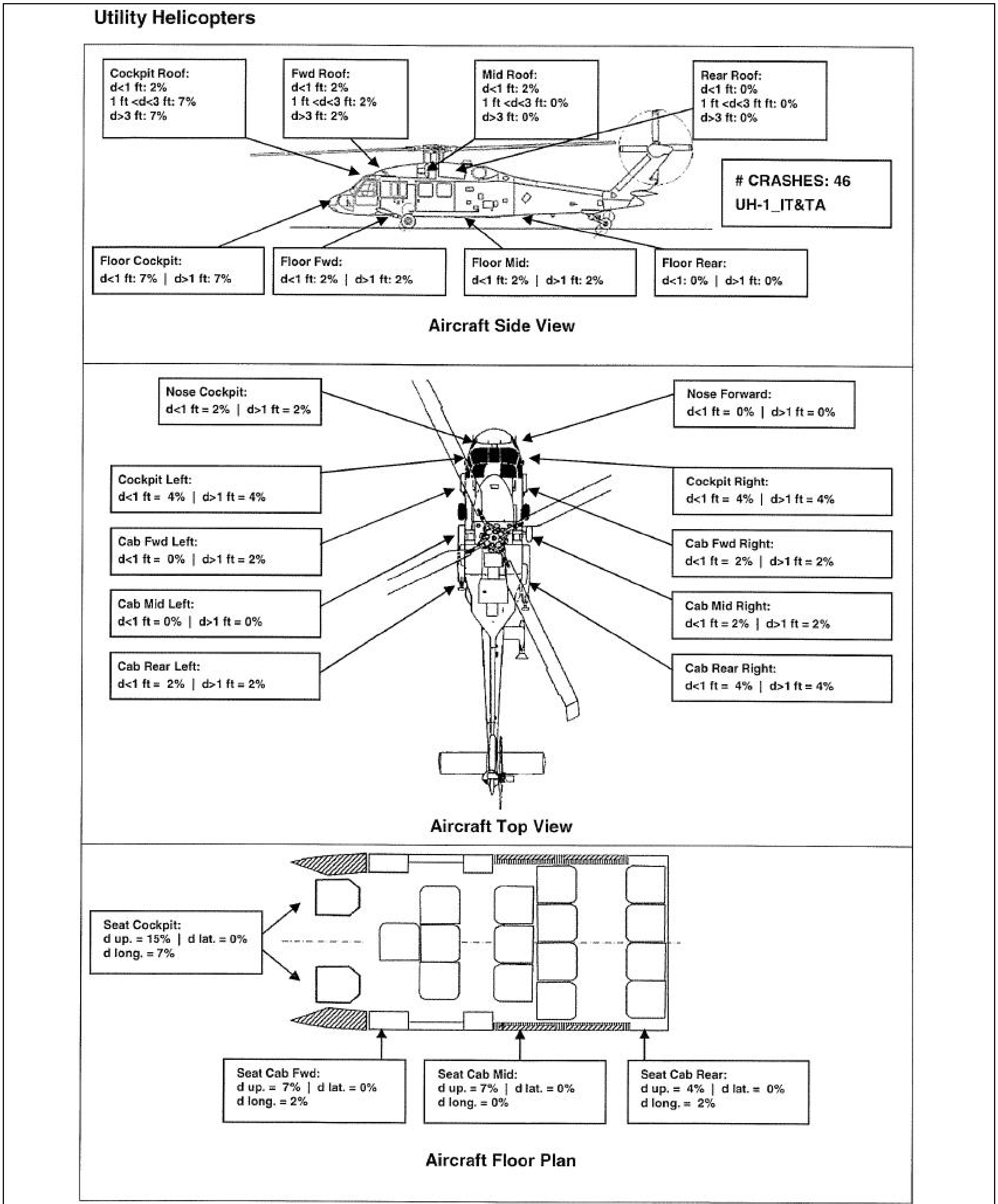

Figure G4-2 – Utility Helicopter Crash/Damage Percentages, UH-1_IT&TA

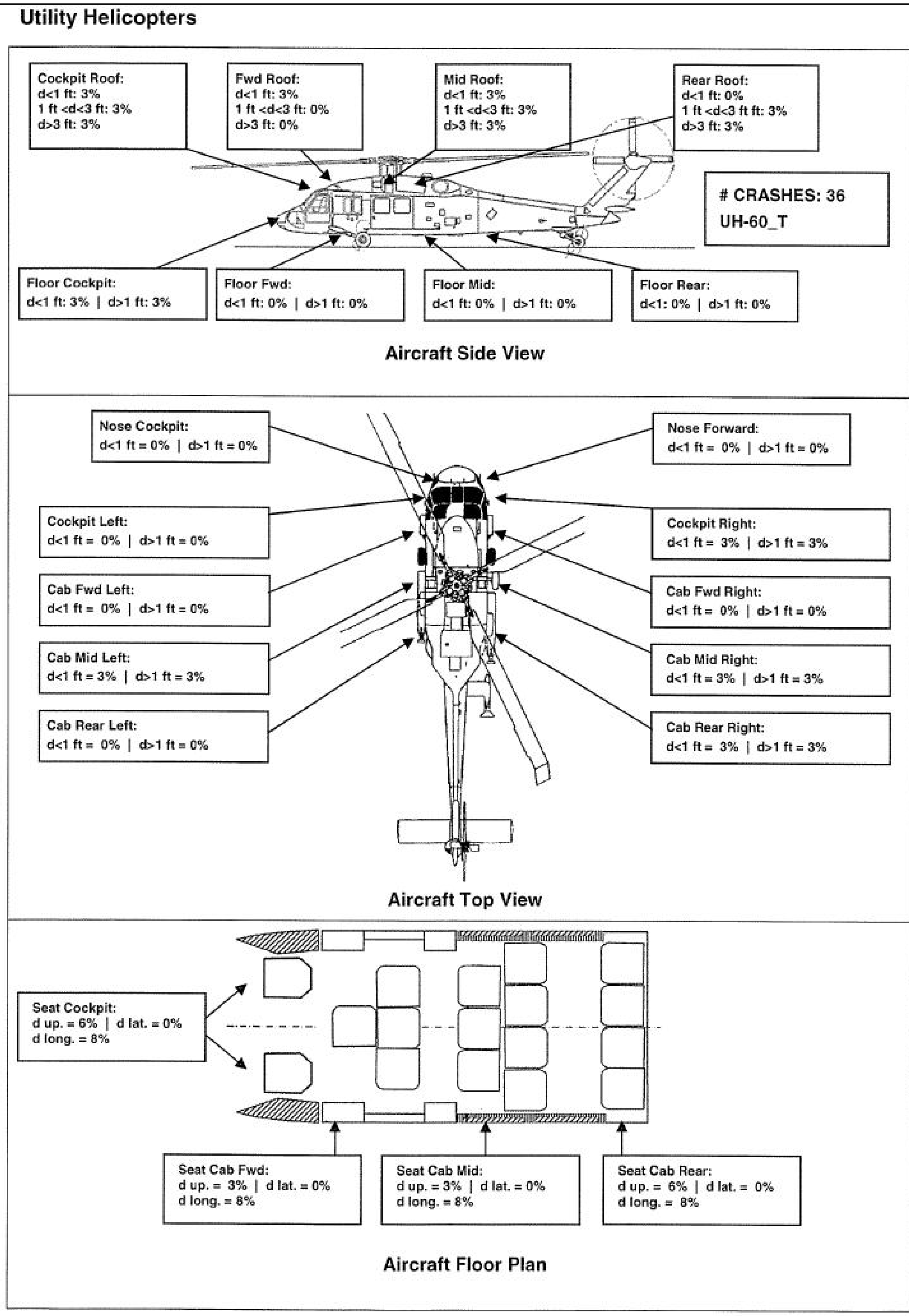

Figure G4-3 – Utility Helicopter Crash/Damage Percentages, UH-60_T

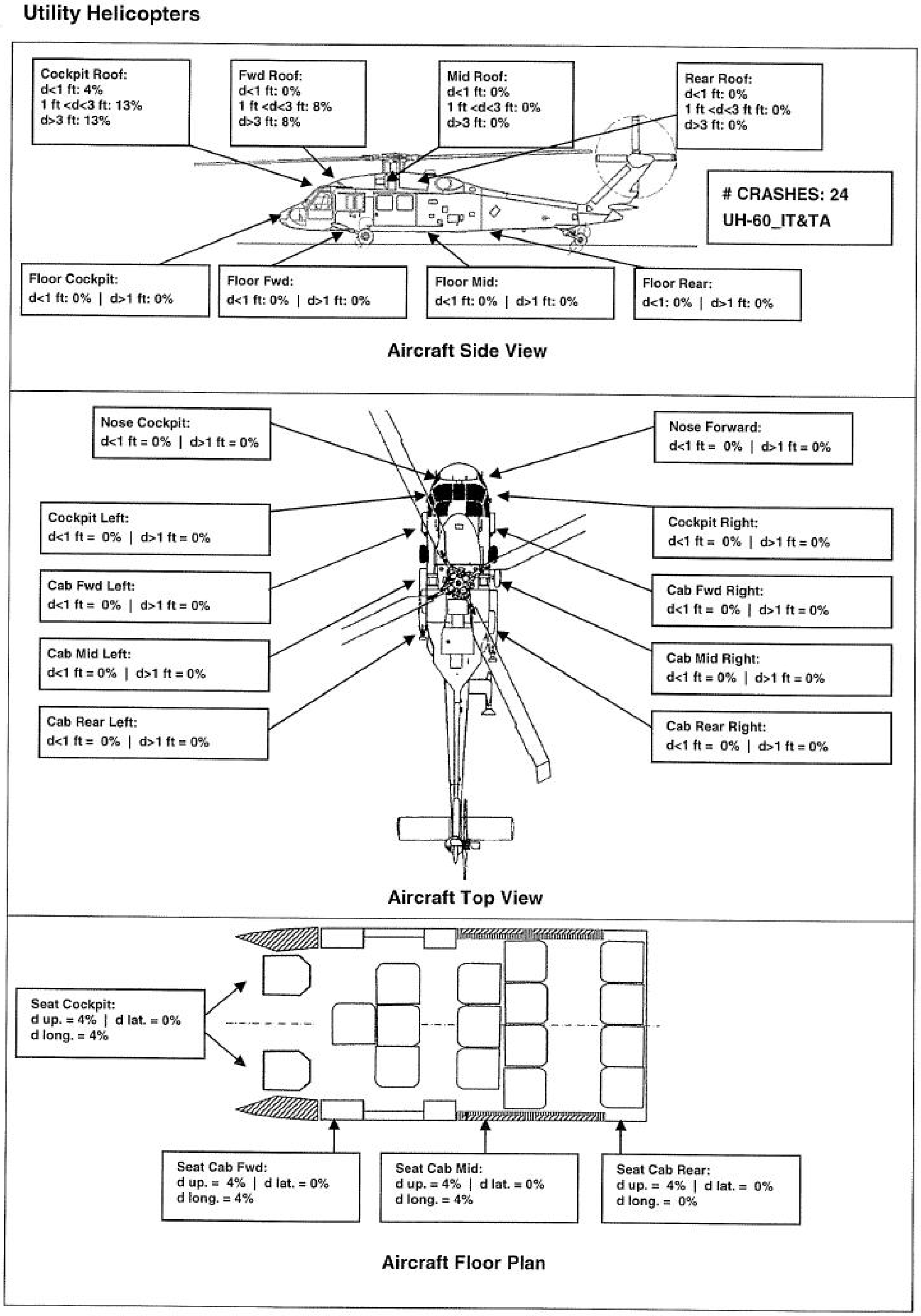

Figure G4-4 – Utility Helicopter Crash/Damage Percentages, UH-60_IT&TA

Appendix H – Injury Distribution Tables

H1 – Fraction of All Injuries in Each Body Region

H2 – Fraction of Occupants Injured in Each Body Region

Appendix H – Injury Distribution Tables

H1 – Fraction of All Injuries in Each Body Region

The data in this appendix indicate the percent of all injuries that occurred during survivable (S=1&2) crashes for the indicated aircraft type and crash type (T or IT&TA). The percentage is determined by dividing the number of injuries that occurred in the body region for the stated population, divided by the total number of injuries reported for that population (all, pilots, crew, or passengers). This information is useful for determining the body region that experiences the greatest fraction of injuries. Knowing where the greatest number of injuries occur may be useful in deciding where to apply resources to prevent the greatest number of injuries, or to determine which regions incur the greatest fraction of all injuries. The injury count includes multiple injuries in the same region on the same individual where recorded.

Revision:

In the original report, the values reported for each body region were incorrect.

In the original report, the data were presented in the form of 'body maps,' as shown on the following page. This presentation was selected to be consistent with the presentation in *Aircraft Crash Survival Design Guide*[1] of 1989 and prior editions. The map on the following page presents the corrected data for the AH-1. With this revision, it was agreed to present all of the data in tabular format rather than map format. While the maps may provide a more compelling presentation, the tabular format is easier to extract data from for further analysis.

[1] *Aircraft Crash Survival Design Guide*, Zimmermann, R.E., Merritt, N.A., prepared for the U.S. Army Aviation Technology Directorate, USAAVSCOM TR 89-D-22A, prepared by Simula, Inc., Phoenix, AZ, December 1989.

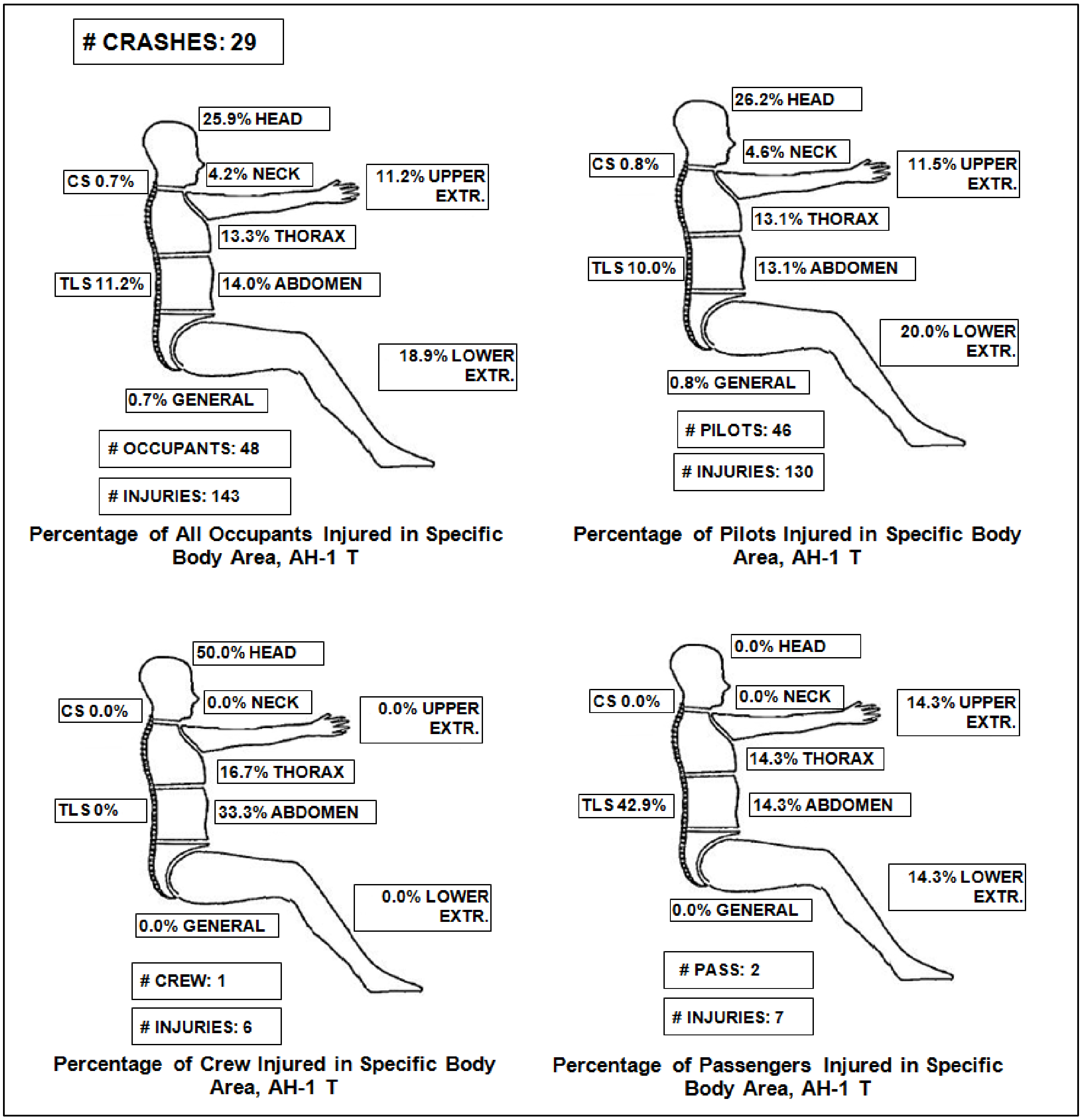

Figure H1-1 – Specific Body Area, Injury Percentages, AH-1_T

Aircraft: AH-1
Crash Type: Terrain Impact T
Number of Crashes: 29

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	48	45	1	2
Injury count	143	130	6	7
Body Region	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**
Head	25.9	26.2	50.0	0.0
Neck	4.2	4.6	0	0.0
Cervical Spine	0.7	0.8	0	0.0
Thoracic Lumbar Spine	11.2	10.0	0	42.9
Thorax	13.3	13.1	16.7	14.3
Abdomen	14.0	13.1	33.3	14.3
Upper Extremities	11.2	11.5	0.0	14.3
Lower Extremities	18.9	20.0	0.0	14.3
General	0.7	0.8	0.0	0.0
Sum	100.1	100.1	100	100.1

Aircraft: AH-1
Crash Type: Inflight Impact above Terrain IT&TA
Number of Crashes: 16

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	28	26	1	1
Injury count	112	104	2	6
Body Region	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**
Head	25.9	26.0	50.0	16.7
Neck	4.5	4.8	0.0	0.0
Cervical Spine	2.7	1.0	0.0	33.3
Thoracic Lumbar Spine	5.4	5.8	0.0	0.0
Thorax	11.6	12.5	0.0	0.0
Abdomen	8.9	8.7	0.0	16.7
Upper Extremities	17.9	19.2	0.0	0.0
Lower Extremities	22.3	22.1	50.0	16.7
General	0.9	0.0	0.0	16.7
Sum	100.1	100.1	100	100.1

Aircraft: AH-64
Crash Type: Terrain Impact T
Number of Crashes: 18

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	31	31	0	0
Injury count	110	110	0	0
Body Region	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**
Head	20.0	20.0	-	-
Neck	2.7	2.7	-	-
Cervical Spine	5.5	5.5	-	-
Thoracic Lumbar Spine	6.4	6.4	-	-
Thorax	20.9	20.9	-	-
Abdomen	6.4	6.4	-	-
Upper Extremities	15.5	15.5	-	-
Lower Extremities	19.1	19.1	-	-
General	3.6	3.6	-	-
Sum	100.1	100.1	-	-

Aircraft: AH-64
Crash Type: Inflight Impact above Terrain IT&TA
Number of Crashes: 17

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	29	28	0	1
Injury count	117	110	0	7
Body Region	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**
Head	25.6	23.6	-	57.1
Neck	8.5	9.1	-	0.0
Cervical Spine	1.7	1.8	-	0.0
Thoracic Lumbar Spine	5.1	4.5	-	14.3
Thorax	17.1	18.2	-	0.0
Abdomen	6.8	7.3	-	0.0
Upper Extremities	14.5	14.5	-	14.3
Lower Extremities	19.7	20.0	-	14.3
General	0.9	0.9	-	0.0
Sum	99.9	99.9	-	100

Aircraft: CH-47
Crash Type: Terrain Impact T
Number of Crashes: 14

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	60	18	22	20
Injury count	136	50	54	32
Body Region	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**
Head	14.5	14.0	14.8	15.6
Neck	4.3	6.0	5.6	0.0
Cervical Spine	2.9	0.0	5.6	3.1
Thoracic Lumbar Spine	4.3	6.0	5.6	0.0
Thorax	13.8	14.0	14.8	12.5
Abdomen	8.0	6.0	7.4	12.5
Upper Extremities	21.0	24.0	18.5	18.8
Lower Extremities	24.6	30.0	20.4	21.9
General	6.5	0.0	7.4	15.6
Sum	99.9	100	100.1	100

Aircraft: CH-47
Crash Type: Inflight Impact above Terrain IT&TA
Number of Crashes: 2

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	5	2	2	1
Injury count	17	11	5	1
Body Region	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**
Head	5.9	9.1	0.0	0.0
Neck	5.9	9.1	0.0	0.0
Cervical Spine	5.9	9.1	0.0	0.0
Thoracic Lumbar Spine	0.0	0.0	0.0	0.0
Thorax	5.9	9.1	0.0	0.0
Abdomen	17.6	18.2	20.0	0.0
Upper Extremities	23.5	18.2	20.0	100
Lower Extremities	29.4	18.2	60.0	0.0
General	5.9	9.1	0.0	0.0
Sum	100	100.1	100	100

Aircraft: OH-6
Crash Type: Terrain Impact T
Number of Crashes: 15

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	26	14	4	8
Injury count	55	25	6	24
Body Region	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**
Head	12.7	12.0	33.3	8.3
Neck	7.3	4.0	0.0	12.5
Cervical Spine	0.0	0.0	0.0	0.0
Thoracic Lumbar Spine	10.9	24.0	0.0	0.0
Thorax	12.7	16.0	33.3	4.2
Abdomen	20.0	16.0	33.3	20.8
Upper Extremities	12.7	0.0	0.0	29.2
Lower Extremities	18.2	16.0	0.0	25.0
General	5.5	12.0	0.0	0.0
Sum	100	100	99.9	100

Aircraft: OH-6
Crash Type: Inflight Impact above Terrain IT&TA
Number of Crashes: 1

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	1	0	1	0
Injury count	1	0	1	0
Body Region	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**
Head	0.0	-	0.0	-
Neck	0.0	-	0.0	-
Cervical Spine	0.0	-	0.0	-
Thoracic Lumbar Spine	0.0	-	0.0	-
Thorax	0.0	-	0.0	-
Abdomen	0.0	-	0.0	-
Upper Extremities	0.0	-	0.0	-
Lower Extremities	100	-	100	-
General	0.0	-	0.0	-
Sum	100	-	100	-

Aircraft: OH-58AC
Crash Type: Terrain Impact T
Number of Crashes: 50

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	78	58	14	6
Injury count	180	135	35	10
Body Region	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**
Head	10.6	12.6	0.0	20.0
Neck	6.1	3.7	11.4	20.0
Cervical Spine	0.6	0.7	0.0	0.0
Thoracic Lumbar Spine	11.7	11.9	11.4	10.0
Thorax	9.4	7.4	17.1	10.0
Abdomen	7.2	7.4	2.9	20.0
Upper Extremities	16.7	18.5	14.3	0.0
Lower Extremities	36.7	37.0	40.0	20.0
General	1.1	0.7	2.9	0.0
Sum	100.1	99.9	100	100

Aircraft: OH-58AC
Crash Type: Inflight Impact above Terrain IT&TA
Number of Crashes: 24

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	48	30	5	13
Injury count	195	123	16	56
Body Region	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**
Head	26.2	31.7	12.5	17.9
Neck	2.6	2.4	12.5	0.0
Cervical Spine	2.6	2.4	6.3	1.8
Thoracic Lumbar Spine	10.3	9.8	18.8	8.9
Thorax	13.8	8.9	18.8	23.2
Abdomen	8.2	6.5	25.0	7.1
Upper Extremities	14.4	13.8	0.0	19.6
Lower Extremities	20.5	22.8	6.3	19.6
General	1.5	1.6	0.0	1.8
Sum	100.1	99.9	100.2	99.9

Aircraft: OH-58D
Crash Type: Terrain Impact T
Number of Crashes: 15

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	27	23	4	0
Injury count	79	69	10	0
Body Region	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**
Head	20.3	21.7	10.0	-
Neck	5.1	5.8	0.0	-
Cervical Spine	0.0	0.0	0.0	-
Thoracic Lumbar Spine	10.1	8.7	20.0	-
Thorax	8.9	8.7	10.0	-
Abdomen	5.1	5.8	0.0	-
Upper Extremities	20.3	17.4	40.0	-
Lower Extremities	30.4	31.9	20.0	-
General	0.0	0.0	0.0	-
Sum	100.2	100	100	-

Aircraft: OH-58D
Crash Type: Inflight Impact above Terrain IT&TA
Number of Crashes: 8

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	18	18	0	0
Injury count	44	44	0	0
Body Region	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**
Head	20.5	20.5	-	-
Neck	0.0	0.0	-	-
Cervical Spine	0.0	0.0	-	-
Thoracic Lumbar Spine	6.8	6.8	-	-
Thorax	25.0	25.0	-	-
Abdomen	4.5	4.5	-	-
Upper Extremities	18.2	18.2	-	-
Lower Extremities	22.7	22.7	-	-
General	2.3	2.3	-	-
Sum	100	100	-	-

Aircraft: UH-1
Crash Type: Terrain Impact T
Number of Crashes: 56

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	153	78	29	46
Injury count	407	206	88	113
Body Region	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**
Head	20.1	22.8	15.9	18.6
Neck	5.7	6.8	1.1	7.1
Cervical Spine	1.5	1.5	1.1	1.8
Thoracic Lumbar Spine	7.4	8.7	8.0	4.4
Thorax	10.6	7.8	9.1	16.8
Abdomen	11.8	8.3	15.9	15.0
Upper Extremities	16.0	13.1	19.3	18.6
Lower Extremities	25.8	30.1	28.4	15.9
General	1.2	1.0	1.1	1.8
Sum	100.1	100.1	99.9	100

Aircraft: UH-1
Crash Type: Inflight Impact above Terrain IT&TA
Number of Crashes: 37

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	137	48	32	57
Injury count	605	264	128	213
Body Region	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**
Head	20.2	18.2	14.1	26.3
Neck	5.8	6.1	8.6	3.8
Cervical Spine	2.3	4.5	0.8	0.5
Thoracic Lumbar Spine	7.6	6.4	8.6	8.5
Thorax	15.5	13.6	25.0	12.2
Abdomen	10.9	8.3	10.9	14.1
Upper Extremities	14.9	16.3	13.3	14.1
Lower Extremities	22.1	26.5	16.4	20.2
General	0.7	0.0	2.3	0.5
Sum	100	99.9	100	100.2

Aircraft: UH-60
Crash Type: Terrain Impact T
Number of Crashes: 17

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	77	31	15	31
Injury count	275	108	52	115
Body Region	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**
Head	21.5	21.3	23.1	20.9
Neck	5.1	7.4	0.0	5.2
Cervical Spine	0.7	0.0	0.0	1.7
Thoracic Lumbar Spine	2.9	4.6	1.9	1.7
Thorax	25.1	13.9	28.8	33.9
Abdomen	9.5	6.5	11.5	11.3
Upper Extremities	12.7	15.7	11.5	10.4
Lower Extremities	17.1	23.1	15.4	12.2
General	5.5	7.4	7.7	2.6
Sum	100.1	99.9	99.9	99.9

Aircraft: UH-60
Crash Type: Inflight Impact above Terrain IT&TA
Number of Crashes: 11

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	53	22	13	18
Injury count	146	79	36	31
Body Region	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**	**Percent of all injuries occurring in body region**
Head	15.8	13.9	19.4	16.1
Neck	2.7	5.1	0.0	0.0
Cervical Spine	0.7	0.0	0.0	3.2
Thoracic Lumbar Spine	10.3	12.7	2.8	12.9
Thorax	24.7	25.3	27.8	19.4
Abdomen	7.5	5.1	16.7	3.2
Upper Extremities	13.0	15.2	16.7	3.2
Lower Extremities	15.8	17.7	11.1	16.1
General	9.6	5.1	5.6	25.8
Sum	100.1	100.1	100.1	99.9

Appendix H – Injury Distribution Tables

H2 – Fraction of Occupants Injured in Each Body Region

The data in this appendix indicate the percent of each population that incurred at least one injury in the applicable region for a given aircraft type and crash type (T or IT&TA). The percentage is determined by dividing the number of persons with an injury recorded in the subject region divided by the number of individuals in the population. This information is useful for determining the body region where the greatest number of people were injured. Knowing the region that was affected for greatest number of people may be useful in conducting cost-benefit analysis or in allocating resources to prevent injury to the maximum number of people. In this analysis, only one injury per body region on the same individual is counted.

Revision:

In the original report, the values reported for each body region were incorrect.

In the original report, the data were presented in the form of 'body maps,' as shown on the following page. This presentation was selected to be consistent with the presentation in *Aircraft Crash Survival Design Guide*[1] of 1989 and prior editions. The map on the following page presents the corrected data for the AH-1. With this revision, it was agreed to present all of the data in tabular format rather than map format. While the maps may provide a more compelling presentation, the tabular format is easier to extract data from for further analysis.

[1] *Aircraft Crash Survival Design Guide*, Zimmermann, R.E., Merritt, N.A., prepared for the U.S. Army Aviation Technology Directorate, USAAVSCOM TR 89-D-22A, prepared by Simula, Inc., Phoenix, AZ, December 1989.

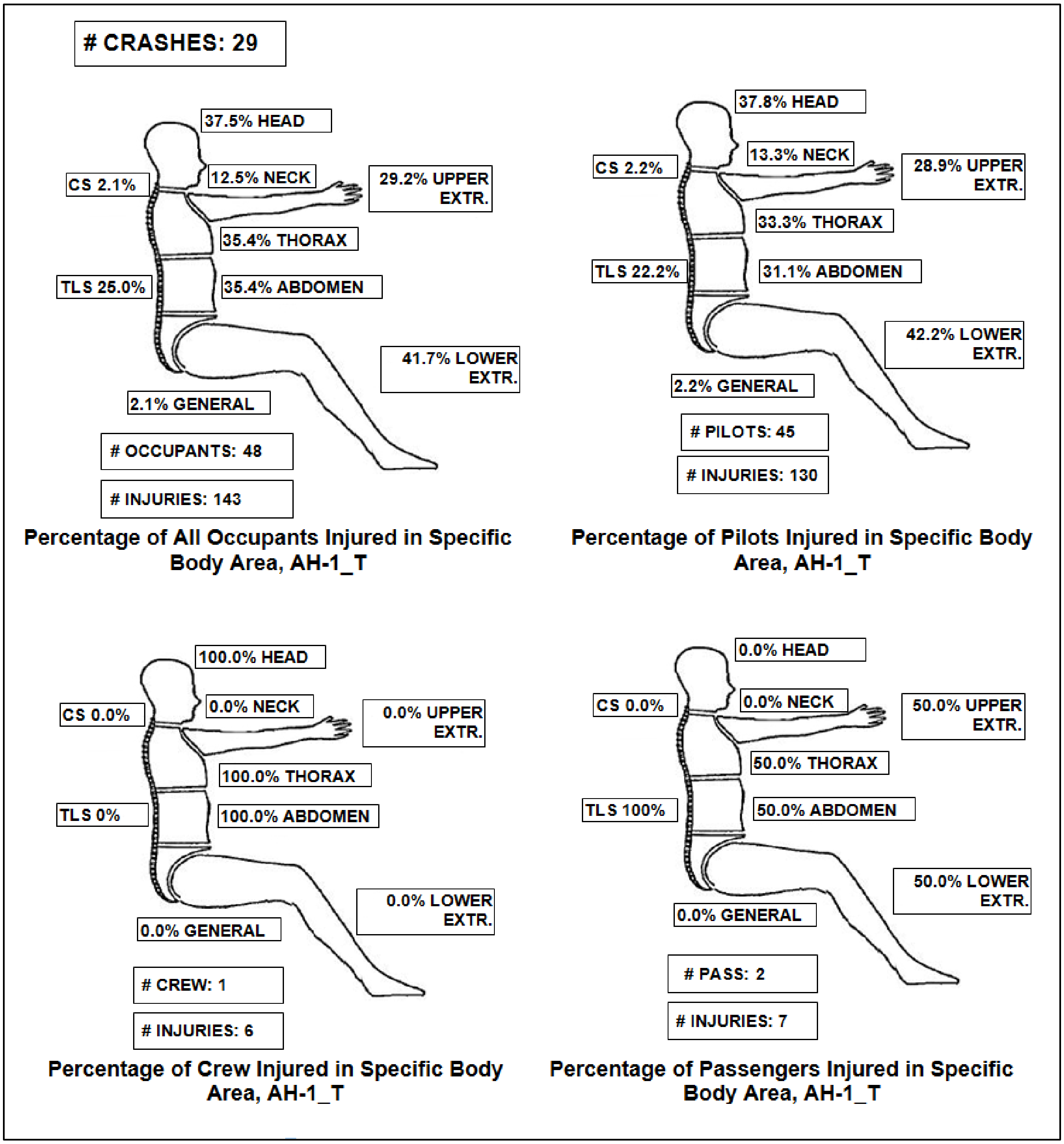

Figure H2-1 – Frequency of Injuries, AH-1_T

Aircraft: AH-1
Crash Type: Terrain Impact T
Number of Crashes: 29

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	48	45	1	2
Injury count	143	130	6	7
Avg. Inj./Occ.	3.0	2.9	6.0	3.5
Body Region	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**
Head	37.5	37.8	100	0.0
Neck	12.5	13.3	0.0	0.0
Cervical Spine	2.1	2.2	0.0	0.0
Thoracic Lumbar Spine	25.0	22.2	0.0	100
Thorax	35.4	33.3	100	50.0
Abdomen	35.4	31.1	100	50.0
Upper Extremities	29.2	28.9	0.0	50.0
Lower Extremities	41.7	42.2	0.0	50.0
General	2.1	2.2	0.0	0.0

Aircraft: AH-1
Crash Type: Inflight Impact above Terrain IT&TA
Number of Crashes: 16

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	28	26	1	1
Injury count	112	104	2	6
Avg. Inj./Occ.	4.0	4.0	2.0	6.0
Body Region	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**
Head	46.4	42.3	100	100
Neck	17.9	19.2	0.0	0.0
Cervical Spine	7.1	3.8	0.0	100
Thoracic Lumbar Spine	14.3	15.4	0.0	0.0
Thorax	32.1	34.6	0.0	0.0
Abdomen	32.1	30.8	0.0	100
Upper Extremities	53.6	57.7	0.0	0.0
Lower Extremities	46.4	42.3	100	100
General	3.6	0.0	0.0	100

Aircraft: AH-64
Crash Type: Terrain Impact T
Number of Crashes: 18

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	31	31	0	0
Injury count	110	110	0	0
Avg. Inj./Occ.	3.5	3.5	-	-
Body Region	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**
Head	48.4	48.4	-	-
Neck	9.7	9.7	-	-
Cervical Spine	9.7	9.7	-	-
Thoracic Lumbar Spine	16.1	16.1	-	-
Thorax	51.6	51.6	-	-
Abdomen	19.4	19.4	-	-
Upper Extremities	45.2	45.2	-	-
Lower Extremities	48.4	48.2	-	-
General	12.9	12.9	-	-

Aircraft: AH-64
Crash Type: Inflight Impact above Terrain IT&TA
Number of Crashes: 17

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	29	28	0	1
Injury count	117	110	0	7
Avg. Inj./Occ.	4.0	3.9	-	7.0
Body Region	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**
Head	65.5	64.3	-	100
Neck	34.5	35.7	-	0.0
Cervical Spine	6.9	7.1	-	0.0
Thoracic Lumbar Spine	17.2	14.3	-	100
Thorax	62.1	64.3	-	0.0
Abdomen	24.1	25.0	-	0.0
Upper Extremities	48.3	46.4	-	100
Lower Extremities	69.0	67.9	-	100
General	3.4	3.6	-	0.0

Aircraft: CH-47
Crash Type: Terrain Impact T
Number of Crashes: 14

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	60	18	22	20
Injury count	136	50	54	32
Avg. Inj./Occ.	2.3	2.8	2.5	1.6
Body Region	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**
Head	26.7	27.8	27.3	25.0
Neck	10.0	16.7	13.6	0.0
Cervical Spine	6.7	0.0	13.6	5.0
Thoracic Lumbar Spine	10.0	16.7	13.6	0.0
Thorax	25.0	27.8	27.3	20.0
Abdomen	16.7	16.7	18.2	15.0
Upper Extremities	38.3	50.0	36.4	30.0
Lower Extremities	48.3	72.2	45.5	30.0
General	15.0	0.0	18.2	25.0

Aircraft: CH-47
Crash Type: Inflight Impact above Terrain IT&TA
Number of Crashes: 2

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	5	2	2	1
Injury count	17	11	5	1
Avg. Inj./Occ.	3.4	5.5	2.5	1.0
Body Region	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**
Head	20.0	50.0	0.0	0.0
Neck	20.0	50.0	0.0	0.0
Cervical Spine	20.0	50.0	0.0	0.0
Thoracic Lumbar Spine	0.0	0.0	0.0	0.0
Thorax	20.0	50.0	0.0	0.0
Abdomen	60.0	100	50.0	0.0
Upper Extremities	80.0	100	50.0	100
Lower Extremities	80.0	100	100	0.0
General	20.0	50.0	0.0	0.0

Aircraft: OH-6
Crash Type: Terrain Impact T
Number of Crashes: 15

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	26	14	4	8
Injury count	55	25	6	24
Avg. Inj./Occ.	2.1	1.8	1.5	3.0
Body Region	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**
Head	23.1	24.1	50.0	12.5
Neck	15.4	7.1	0.0	37.5
Cervical Spine	0.0	0.0	0.0	0.0
Thoracic Lumbar Spine	15.4	28.6	0.0	0.0
Thorax	23.1	21.4	50.0	12.5
Abdomen	42.3	28.6	50.0	62.5
Upper Extremities	15.4	0.0	0.0	50.0
Lower Extremities	26.9	21.4	0.0	50.0
General	11.5	21.4	0.0	0.0

Aircraft: OH-6
Crash Type: Inflight Impact above Terrain IT&TA
Number of Crashes: 1

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	1	0	1	0
Injury count	1	0	1	0
Avg. Inj./Occ.	1	-	1	-
Body Region	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**
Head	0.0	-	0.0	-
Neck	0.0	-	0.0	-
Cervical Spine	0.0	-	0.0	-
Thoracic Lumbar Spine	0.0	-	0.0	-
Thorax	0.0	-	0.0	-
Abdomen	0.0	-	0.0	-
Upper Extremities	0.0	-	0.0	-
Lower Extremities	100	-	100	-
General	0.0	-	0.0	-

Aircraft: OH-58AC
Crash Type: Terrain Impact T
Number of Crashes: 50

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	78	58	14	6
Injury count	180	135	35	10
Avg. Inj./Occ.	2.3	2.3	2.5	1.7
Body Region	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**
Head	19.2	24.1	0.0	16.7
Neck	14.1	8.6	28.6	33.3
Cervical Spine	1.3	1.7	0.0	0.0
Thoracic Lumbar Spine	20.5	20.7	21.4	16.7
Thorax	19.2	15.5	35.7	16.7
Abdomen	14.1	15.5	7.1	16.7
Upper Extremities	35.9	39.7	35.7	0.0
Lower Extremities	55.1	58.6	50.0	33.3
General	2.6	1.7	7.1	0.0

Aircraft: OH-58AC
Crash Type: Inflight Impact above Terrain IT&TA
Number of Crashes: 24

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	48	30	5	13
Injury count	195	123	16	56
Avg. Inj./Occ.	4.1	4.1	3.2	4.3
Body Region	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**
Head	45.8	53.3	20.0	38.5
Neck	10.4	10.0	40.0	0.0
Cervical Spine	10.4	10.0	20.0	7.7
Thoracic Lumbar Spine	27.1	23.3	60.0	23.1
Thorax	45.8	30.0	60.0	76.9
Abdomen	27.1	23.3	60.0	23.1
Upper Extremities	41.7	46.7	0.0	46.2
Lower Extremities	56.3	63.3	20.0	53.8
General	6.3	6.7	0.0	7.7

Aircraft: OH-58D
Crash Type: Terrain Impact T
Number of Crashes: 15

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	27	23	4	0
Injury count	79	69	10	0
Avg. Inj./Occ.	2.9	3.0	2.5	-
Body Region	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**
Head	37.0	39.1	25.0	-
Neck	14.8	17.4	0.0	-
Cervical Spine	0.0	0.0	0.0	-
Thoracic Lumbar Spine	25.9	21.7	50.0	-
Thorax	22.2	21.7	25.0	-
Abdomen	14.8	17.4	0.0	-
Upper Extremities	51.9	47.8	75.0	-
Lower Extremities	63.0	65.2	50.0	-
General	0.0	0.0	0.0	-

Aircraft: OH-58D
Crash Type: Inflight Impact above Terrain IT&TA
Number of Crashes: 8

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	18	18	0	0
Injury count	44	44	0	0
Avg. Inj./Occ.	2.4	2.4	-	-
Body Region	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**
Head	44.4	44.4	-	-
Neck	0.0	0.0	-	-
Cervical Spine	0.0	0.0	-	-
Thoracic Lumbar Spine	16.7	16.7	-	-
Thorax	44.4	44.4	-	-
Abdomen	11.1	11.1	-	-
Upper Extremities	38.9	38.9	-	-
Lower Extremities	38.9	38.9	-	-
General	5.6	5.6	-	-

Aircraft: UH-1
Crash Type: Terrain Impact T
Number of Crashes: 56

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	153	78	29	46
Injury count	407	206	88	113
Avg. Inj./Occ.	2.7	2.6	3.1	2.5
Body Region	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**
Head	32.0	30.8	37.9	30.4
Neck	15.0	17.9	3.4	17.4
Cervical Spine	3.9	3.8	3.4	4.3
Thoracic Lumbar Spine	13.7	14.1	17.2	10.9
Thorax	22.9	16.7	24.1	32.6
Abdomen	28.8	21.8	41.4	32.6
Upper Extremities	34.6	30.8	37.9	39.1
Lower Extremities	52.9	61.5	58.6	34.8
General	2.6	2.6	3.4	2.2

Aircraft: UH-1
Crash Type: Inflight Impact above Terrain IT&TA
Number of Crashes: 37

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	137	48	32	57
Injury count	605	264	128	213
Avg. Inj./Occ.	4.4	5.5	4.0	3.7
Body Region	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**
Head	52.6	62.5	40.6	50.9
Neck	20.4	22.9	28.1	14.0
Cervical Spine	5.8	12.5	3.1	1.8
Thoracic Lumbar Spine	24.1	25.0	21.9	24.6
Thorax	46.0	54.2	56.3	33.3
Abdomen	34.3	35.4	37.5	31.6
Upper Extremities	43.1	52.1	43.8	35.1
Lower Extremities	61.3	81.3	46.9	52.6
General	2.9	0.0	9.4	1.8

Aircraft: UH-60
Crash Type: Terrain Impact T
Number of Crashes: 17

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	77	31	15	31
Injury count	275	108	52	115
Avg. Inj./Occ.	3.6	3.5	3.5	3.7
Body Region	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**
Head	53.2	48.4	40.0	64.5
Neck	18.2	25.8	0.0	19.4
Cervical Spine	2.6	0.0	0.0	6.5
Thoracic Lumbar Spine	6.5	9.7	6.7	3.2
Thorax	50.6	35.5	66.7	58.1
Abdomen	31.2	19.4	33.3	41.9
Upper Extremities	33.8	35.5	40.0	29.0
Lower Extremities	44.2	51.6	40.0	38.7
General	14.3	16.1	20.0	9.7

Aircraft: UH-60
Crash Type: Inflight Impact above Terrain IT&TA
Number of Crashes: 11

Body Region	All Occupants	Pilots	Crew	Passengers
Person count	53	22	13	18
Injury count	146	79	36	31
Avg. Inj./Occ.	2.8	3.6	2.8	1.7
Body Region	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**	**Percent of all occupants injured in body region**
Head	28.3	36.4	23.1	22.2
Neck	7.5	18.2	0.0	0.0
Cervical Spine	1.9	0.0	0.0	5.6
Thoracic Lumbar Spine	17.0	27.3	7.7	11.1
Thorax	41.5	50.0	46.2	27.8
Abdomen	17.0	18.2	30.8	5.6
Upper Extremities	24.5	36.4	30.8	5.6
Lower Extremities	30.2	45.5	15.4	22.2
General	26.4	18.2	15.4	44.4

Appendix I – Severe Injury Fraction – Velocity Plots

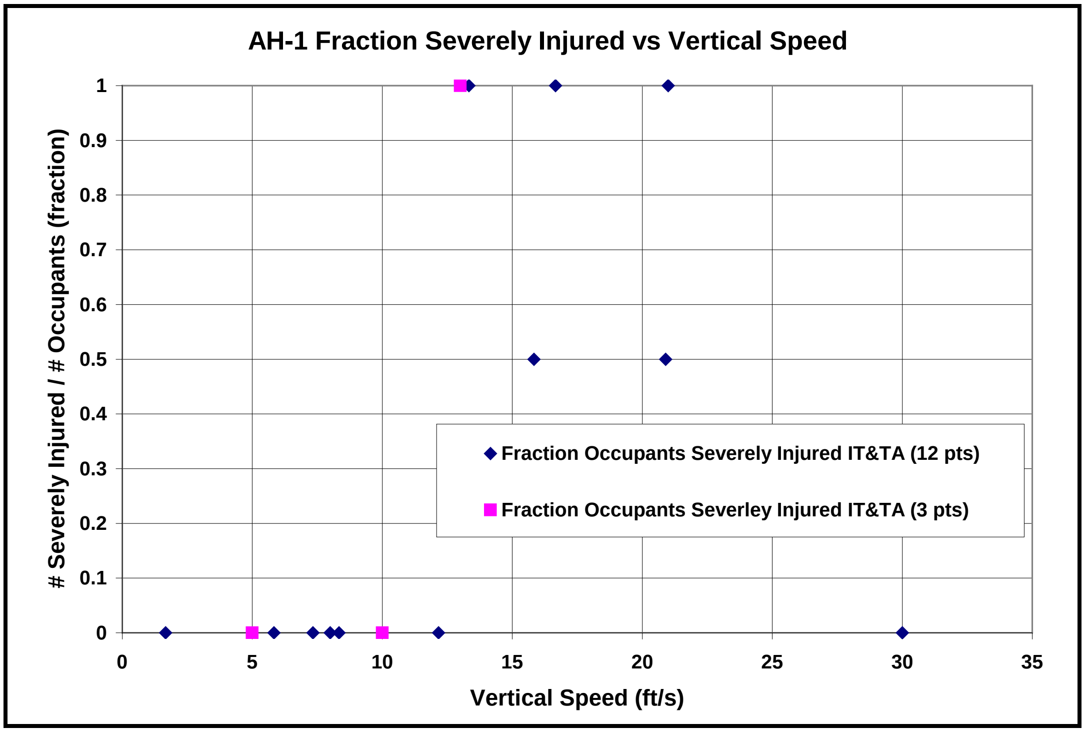

Figure I-1 – AH-1 Fraction Severely Injured vs. Vertical Speed

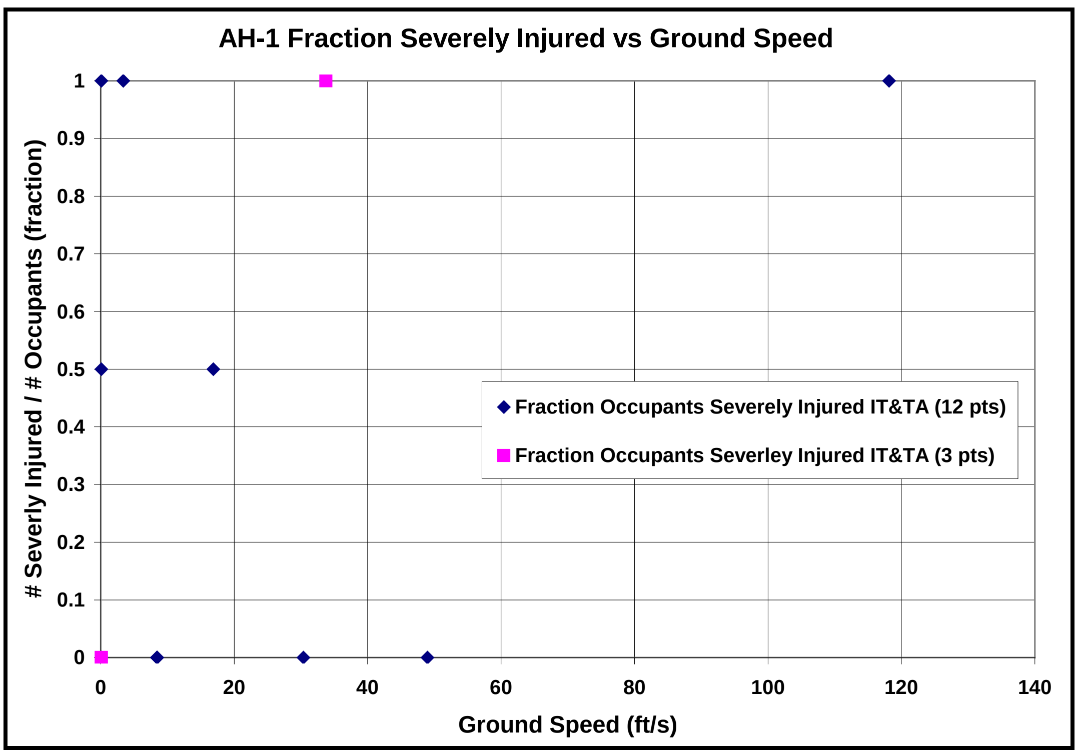

Figure I-2 – AH-1 Fraction Severely Injured vs. Ground Speed

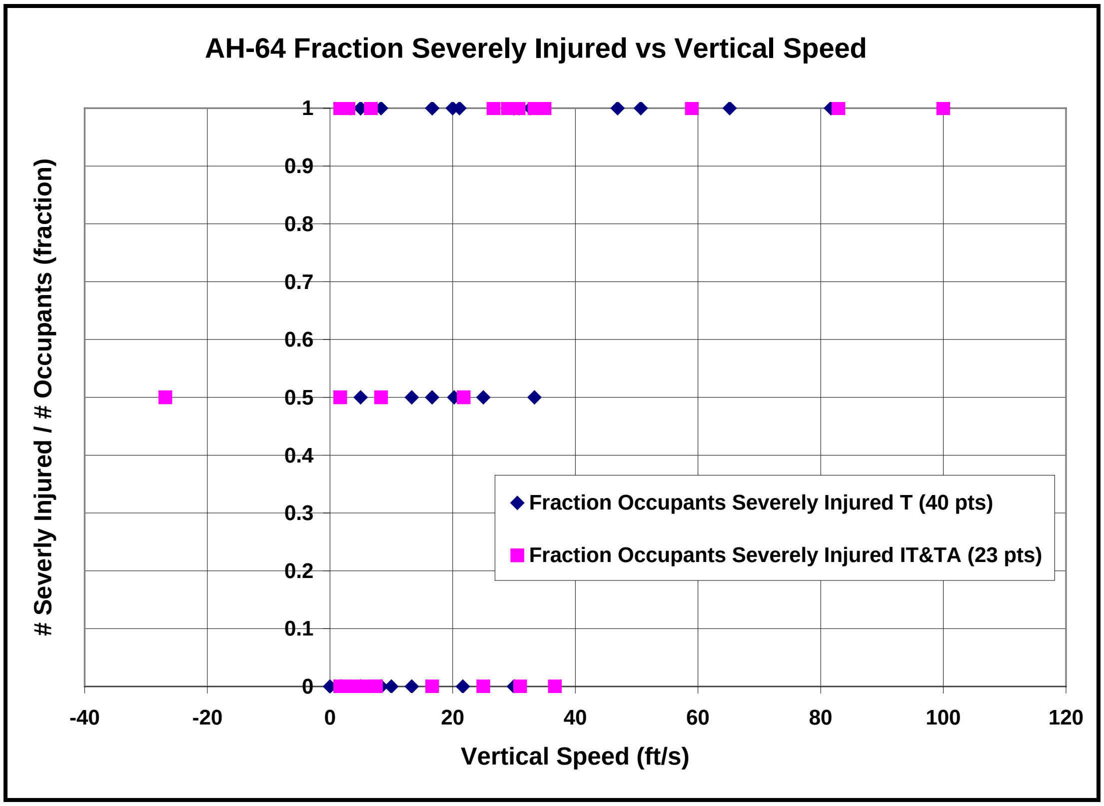

Figure I-3 – AH-64 Fraction Severely Injured vs. Vertical Speed

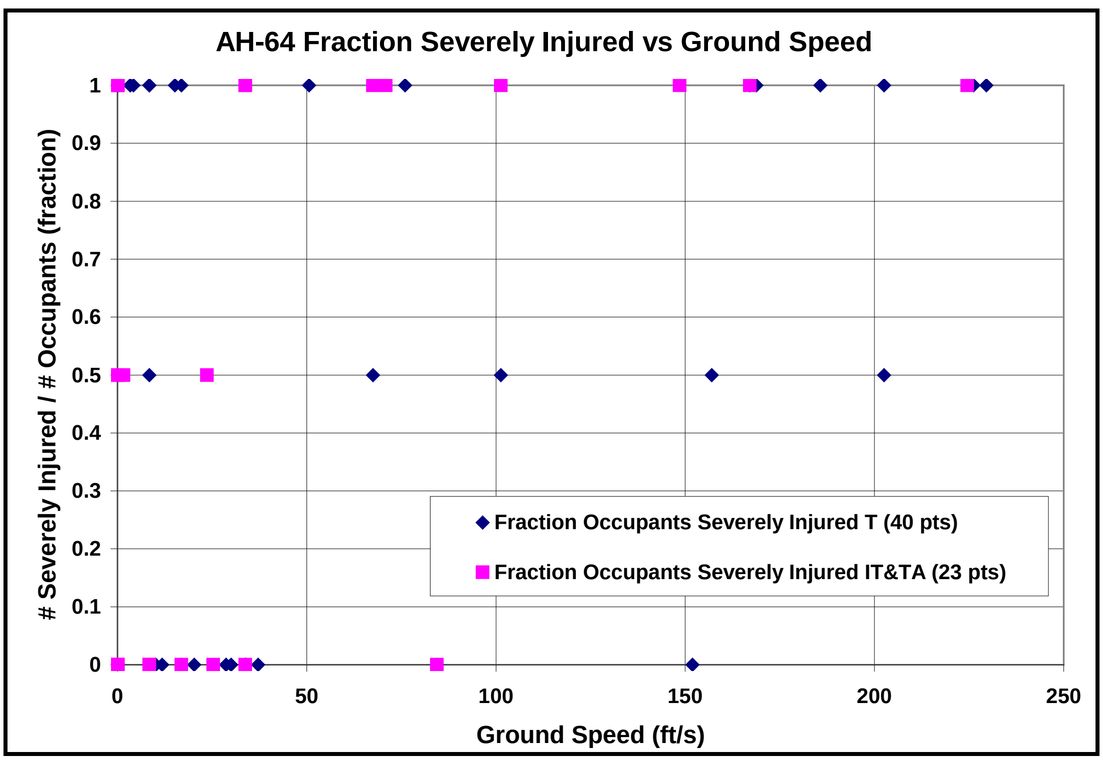

Figure I-4 – AH-64 Fraction Severely Injured vs. Ground Speed

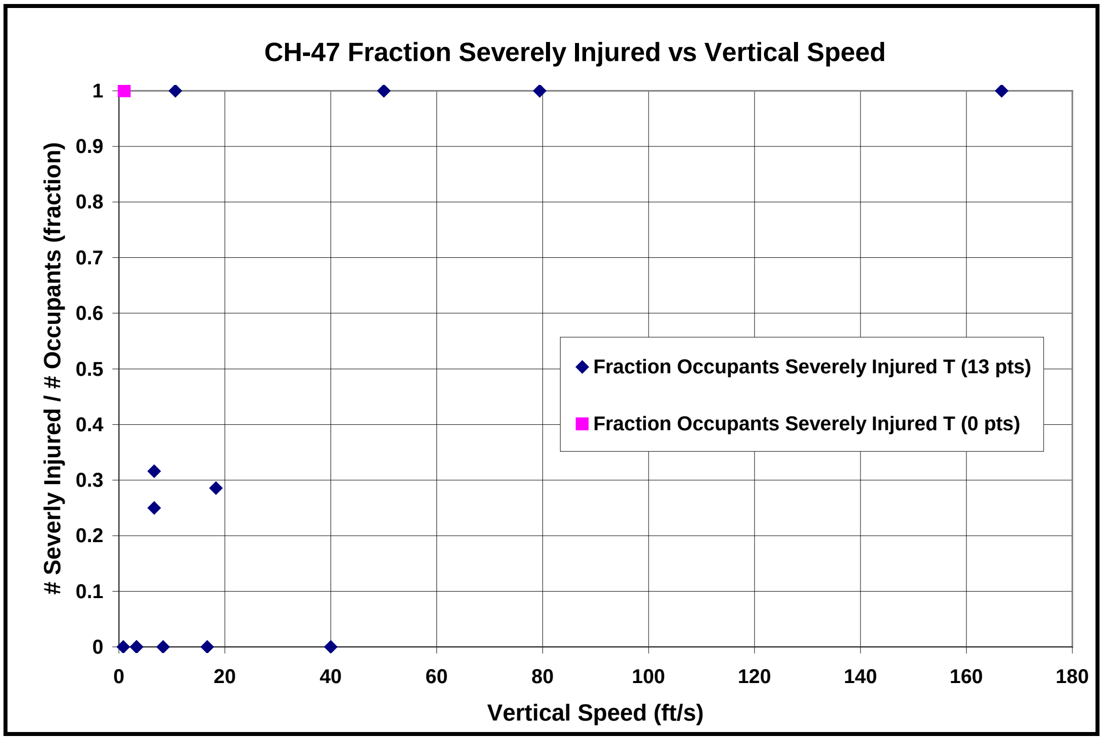

Figure I-5 – CH-47 Fraction Severely Injured vs. Vertical Speed

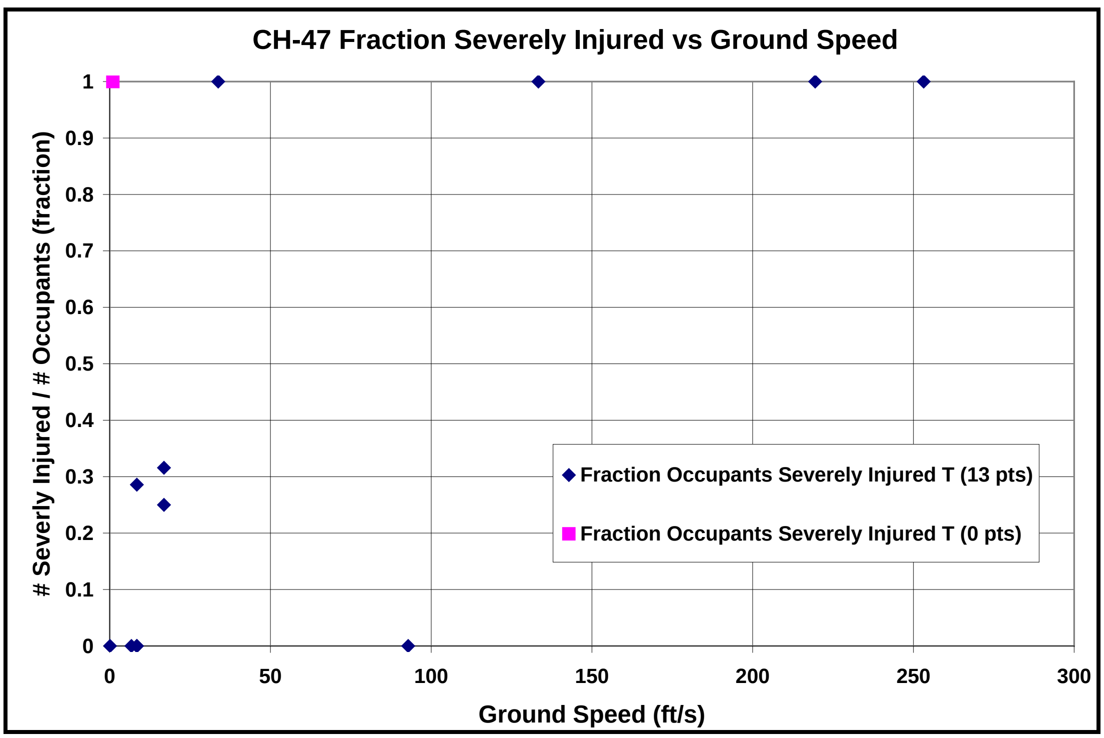

Figure I-6 – CH-47 Fraction Severely Injured vs. Ground Speed

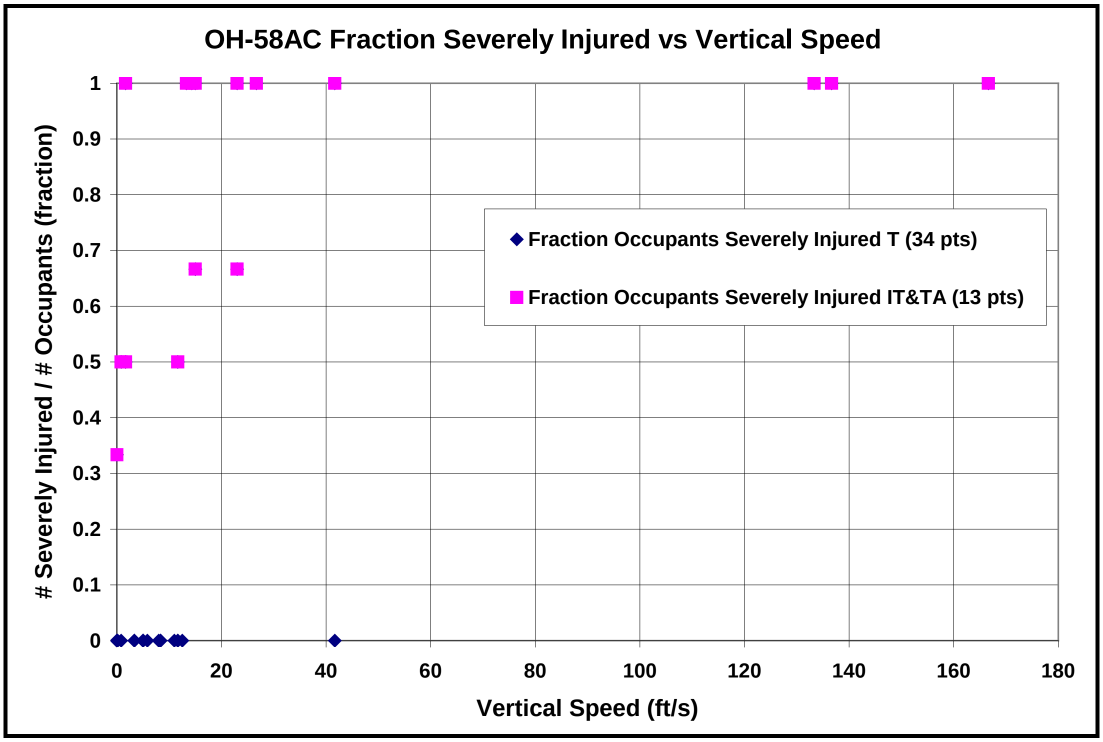

Figure I-7 – OH-58AC Fraction Severely Injured vs. Vertical Speed

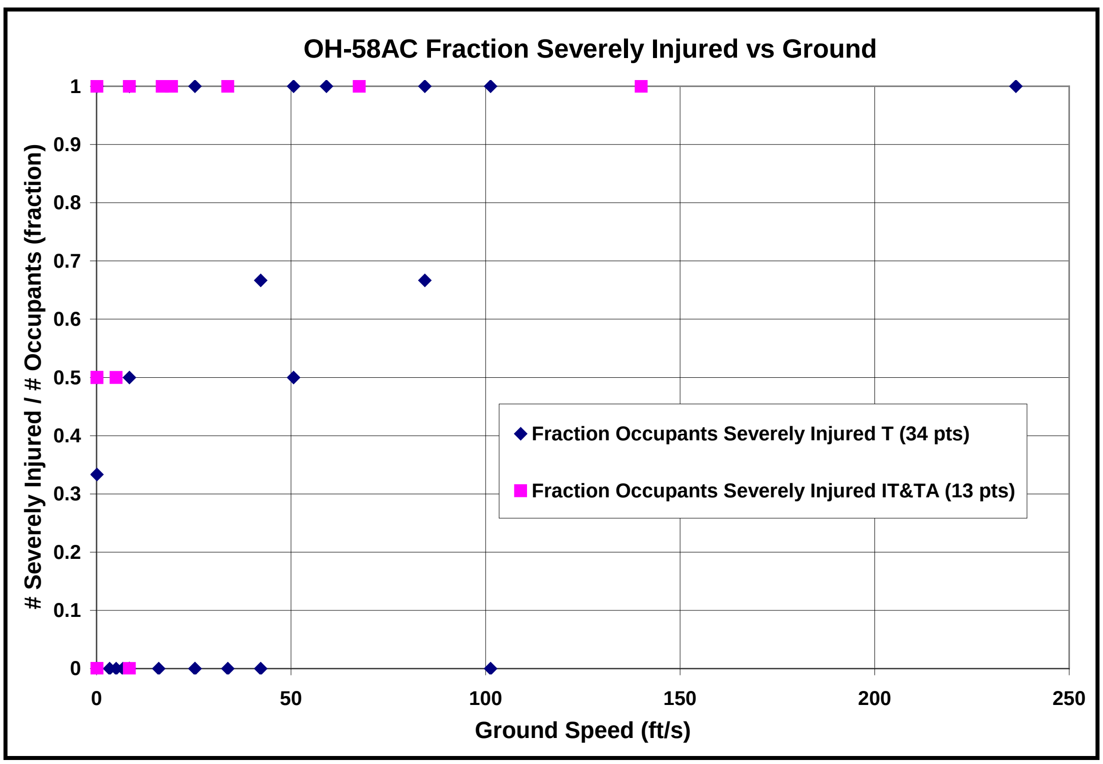

Figure I-8 – OH-58AC Fraction Severely Injured vs. Ground Speed

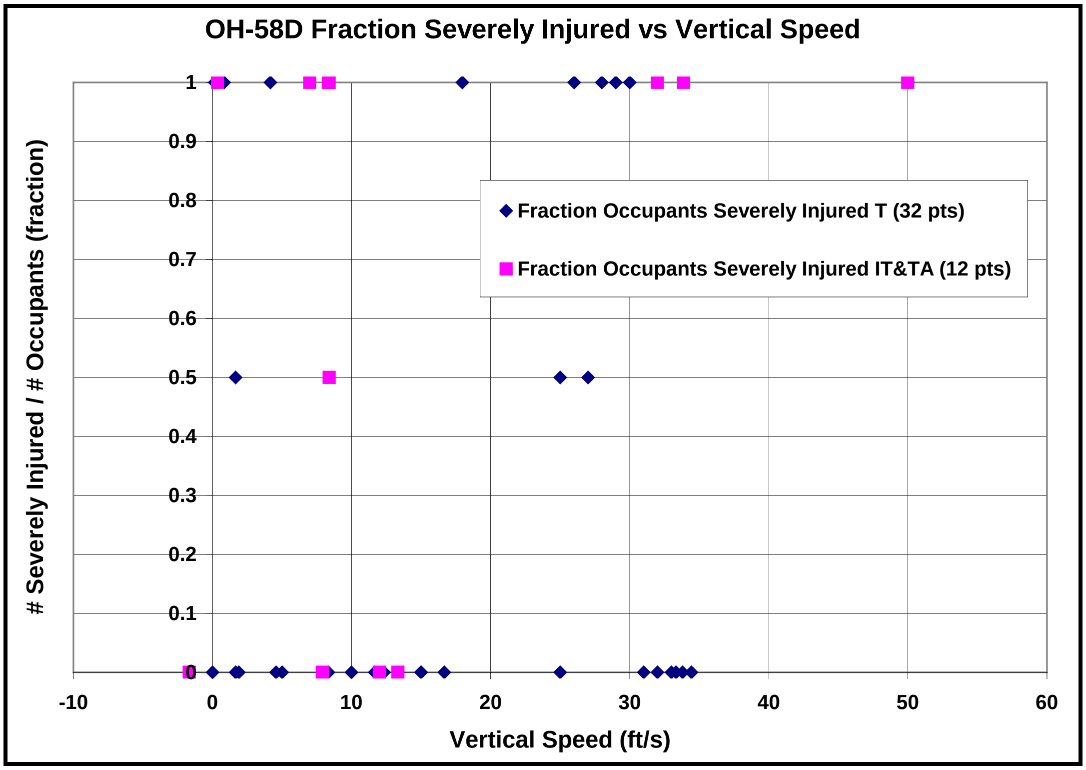

Figure I-9 – OH-58D Fraction Severely Injured vs. Vertical Speed

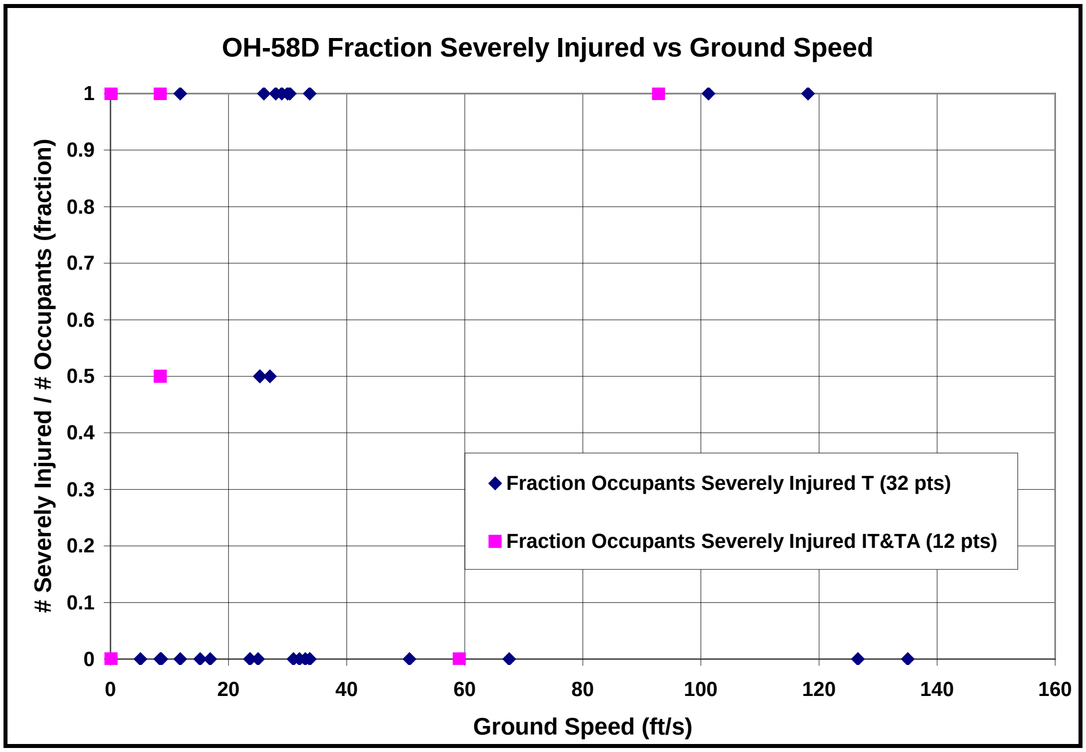

Figure I-10 – OH-58D Fraction Severely Injured vs. Ground Speed

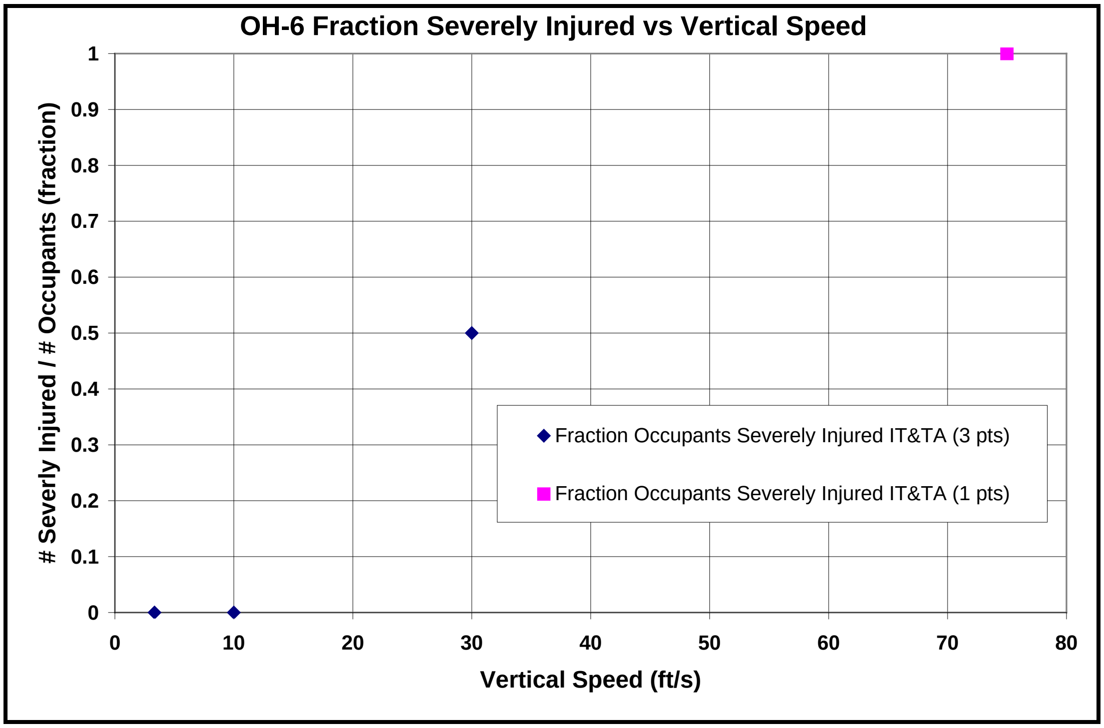

Figure I-11 – OH-6 Fraction Severely Injured vs. Vertical Speed

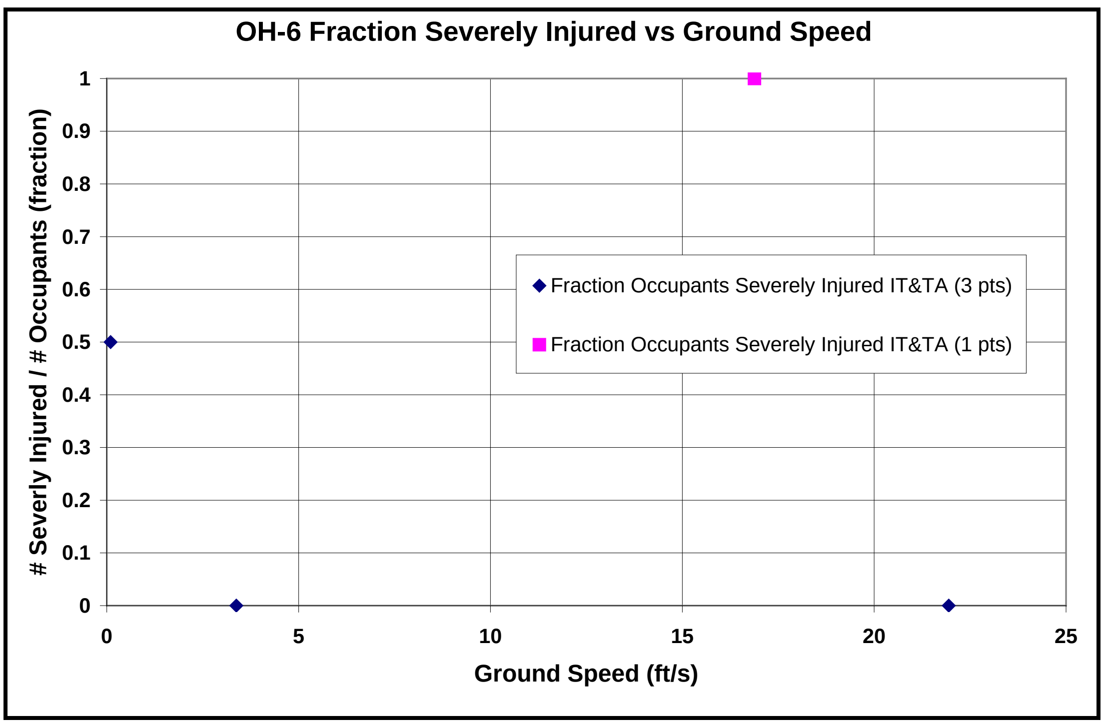

Figure I-12 – OH-6 Fraction Severely Injured vs. Ground Speed

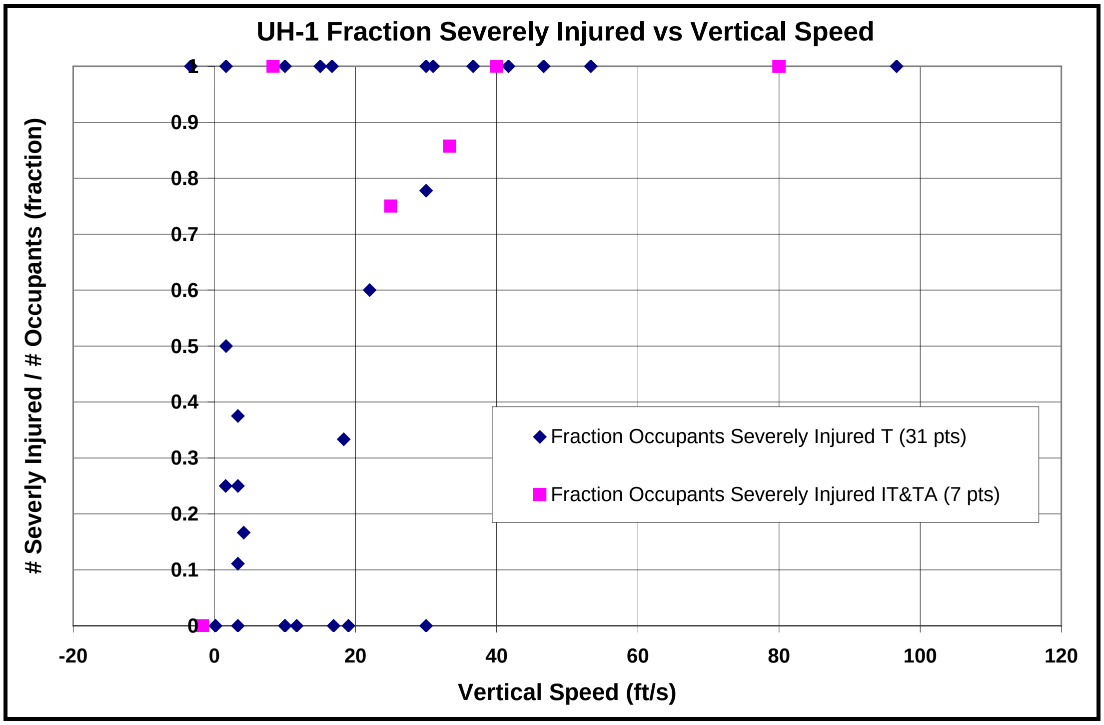

Figure I-13 – UH-1 Fraction Severely Injured vs. Vertical Speed

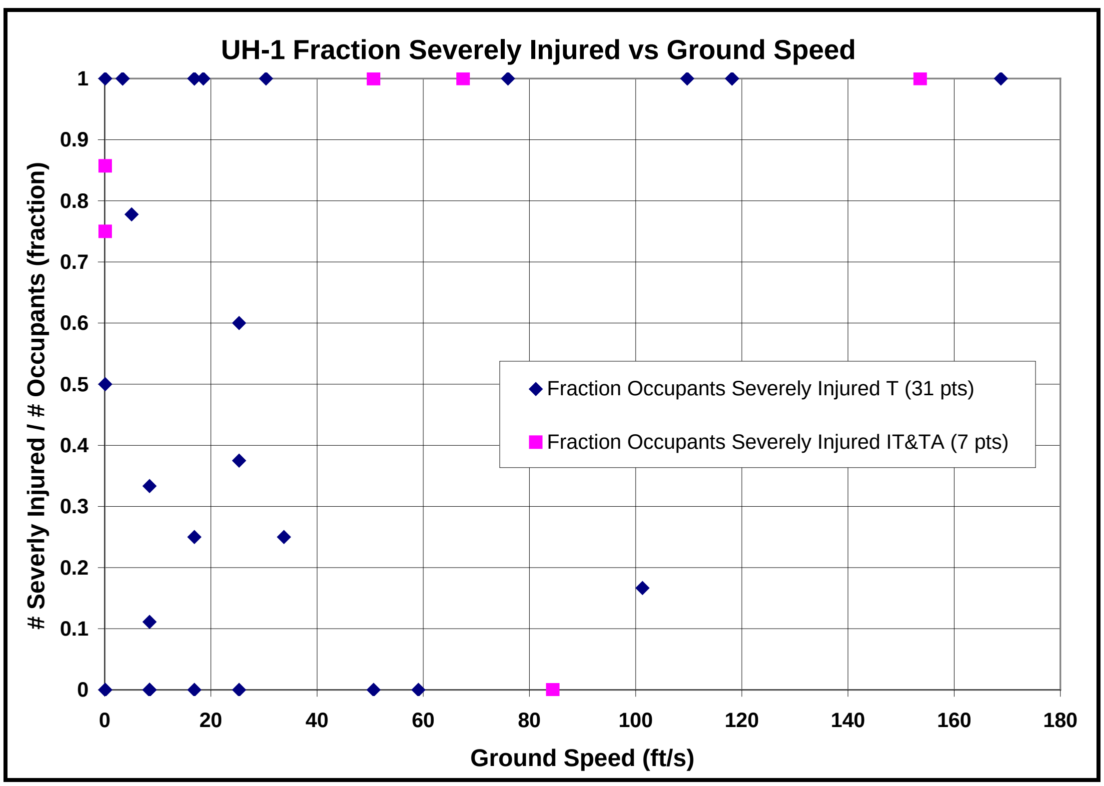

Figure I-14 – UH-1 Fraction Severely Injured vs. Ground Speed

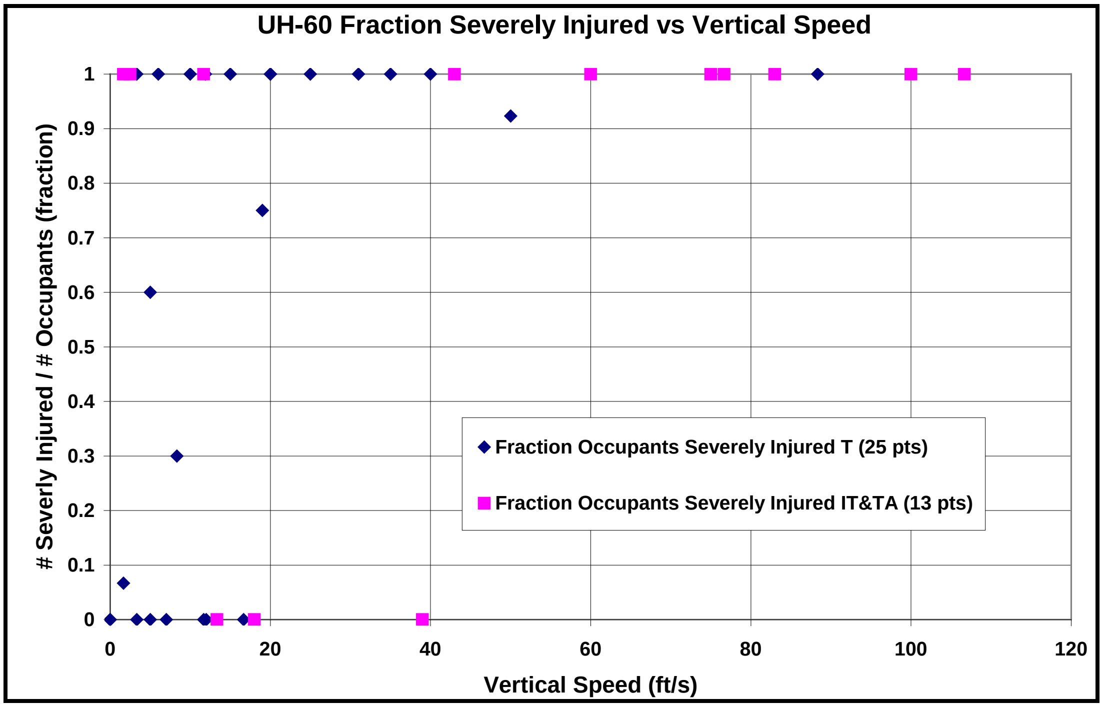

Figure I-15 – UH-60 Fraction Severely Injured vs. Vertical Speed

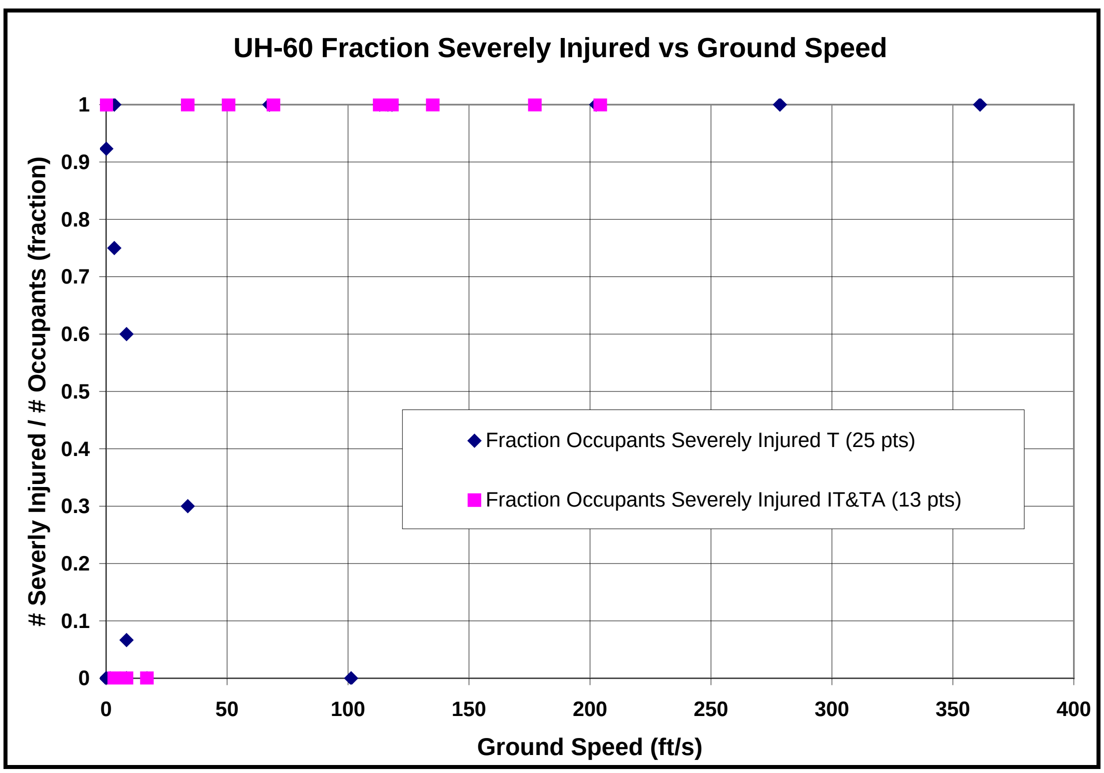

Figure I-16 – UH-60 Fraction Severely Injured vs. Ground Speed

Appendix J – Injury Mechanism & Causation Tables

Injury Mechanisms & Causation Tables, by Aircraft and Crash Type

AH-1

AH-1 T Crashes – Pilots

AH-1-T	7 pilots severely injured	37 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Head – 19 injuries	Struck by / experienced multiple injury mech. (4) Struck gunsight (2) Struck internal object (2) Struck by external object (2)	External obj. penetrated occ. space (3) Helmet exceed design human tolerance (2) Torso restraint allowed excess motion (2)
Thorax – 6 Injuries	Struck against seat (2) Multiple Injury Mechanisms (1)	External object penetrated occupiable space (1) Body part flailed excessively (1)
Abdomen – 4 Injuries	Struck by unknown /unclassified (1) Struck against seat (1)	Unknown object penetrated occupiable space (1) Body part flailed excess motion (1)

AH-1 IT&TA Crashes – Pilots

AH-1-IT&TA	3 pilots severely injured	25 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Head – 10 injuries	Struck gunsight (8)	Restraint allowed excess motion (4) Helmet allowed design & human tolerance (2) Qualifier displace outside aircraft (2)
Upper Extremities – 4 Injuries	Unknown (2)	Unknown (2)
Abdomen – 3 Injuries	Unknown /unclassified (1)	Unknown / unclassified (1)

AH-64

AH-64 T Crashes – Pilots

AH-64-T	6 pilots severely injured	31 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Head – 10 injuries	Excessive deceleration (5) Struck internal object (2) Struck gunsight (1) Struck cyclic (1)	Structural displaced laterally (2) Impact exceed human tolerance (2) Torso restraint improper use (2)
Cervical Spine – 6 Injuries	Excessive deceleration (6)	Body part absorbed excess loading (5) Impact exceed human & design limits (1)
Thorax – 5 Injuries	Excessive deceleration (2) Struck internal obj. (1) Struck armor (1)	Body part exceeded human tolerance (3) Torso restraint allowed excess motion (1) Lap belt not used properly (1)

AH-64 IT&TA Crashes – Pilots

AH-64-IT&TA	6 pilots severely injured	33 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Head – 11 injuries	Struck gunsight (4) Multiple injury mech. (3) Excessive deceleration (1)	Structural displaced laterally (2) Impact exceed human tolerance (2) Torso restraint improper use (2)
Thorax – 6 Injuries	Excessive deceleration (2) Struck internal obj. (1) Struck by Intruding obj. (1)	Body part absorbed excess loading (2) Torso restraint allowed excess motion (2) Body part broke excess motion (1)
Thoracic Lumbar Spine – 4 Injuries	Struck against seat (3) Excessive deceleration (1)	Torso restraint allowed excess motion (2) Seat not used properly (1) Body part absorbed excess load (1)

CH-47

CH-47 T Crashes – Pilots, Crew, Passengers

CH-47-T – Pilots	3 pilots severely injured	18 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Thorax – 5 injuries	Exposed to excess deceleration (2) Struck against restraint (1)	Impact caused excess loading (2) Torso restraint absorbed excess loading (1)
Lower Extremities – 4 Injuries	Exposed to multiple injury mechanisms (1)	Structure collapsed occupiable space (1)
Head – 3 Injuries	No data reported ( )	No data reporte ( )

CH-47-T – Crew	5 Crew severely injured	20 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Thorax – 5 injuries	Struck against structure (3)	Impact caused excess motion (2) Structure collapse occupiable space (1)
General – 4 Injuries	Aircraft fire (2)	Aircraft ignited fuel (2)
Cervical Spine – 3 Injuries	Struck against structure (1) Experienced excess deceleration (1)	Monkey harness allowed excess motion (2)

CH-47-T – Pax	5 Pax severely injured	6 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
General – 4 Injuries	No data reported ( )	No data reported ( )
Head – 1 Injury	No data reported ( )	No data reported ( )
Upper Extremities – 1 Injuries	No data reported ( )	No data reported ( )

CH-47

CH-47 IT&TA Crashes – Pilots, Crew, Passengers

CH-47-IT&TA – Pilots	1 pilots severely injured	6 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
General – 1 Injury	Exposed to fire (1)	
Head – 1 Injuries	Not reported (1)	No data reported ( )
Neck – 1 Injuries	Experienced excess deceleration (1)	Impact caused excessive loading (1)

CH-47-IT&TA – Crew	0 Crew severely injured	0 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**

CH-47-IT&TA – Pax	0 Pax severely injured	0 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**

UH-1
UH-1 T Crashes – Pilots, Crew, Passengers

UH-1-T – Pilots	5 pilots severely injured	29 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Head – 14 injuries	Struck against windshield (3) Struck against instrument panel (1)	Seat displaced human & design limits (2) Helmet absorbed collapsed (1) Impact caused excess motion (1)
Thorax – 5 Injuries	No data reported ( )	No data reported ( )
Thoracic Lumbar Spine – 4 Injuries	Experienced excess deceleration (2)	Seat absorbed excess loading (1) Restraint system allowed excessively (sic) (1)

UH-1-T – Crew	3 crew severely injured	14 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Thoracic Lumbar Spine – 6 injuries	Thrown from aircraft (3) Experienced excessive deceleration (3)	Restraint system not used properly (3) Restraint system not provided excess motion (2) Impact exceeded human & design tolerance (1)
Head – 2 Injuries	Struck by internal objects (1) Thrown from aircraft (1)	Internal objects injured unknown (1) Restraint system not used properly (1)
Thorax – 2 Injuries	Thrown from aircraft (2)	Restraint system not used properly (2)

UH-1-T – Passengers	5 crew severely injured	25 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Head – 5 Injuries	No data reported ( )	No data reported ( )
Thorax – 4 Injuries	No data reported ( )	No data reported ( )
Thoracic Lumbar Spine – 3 injuries	Experienced excess deceleration (1)	Impact exceeded vertical (1)

UH-1

UH-1 IT&TA Crashes – Pilots, Crew, & Passengers

UH-1-IT&TA – Pilots	12 pilots severely injured	75 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Head – 19 injuries	Struck by intruding object (4) Struck by / against structure (2) Struck against seat (1)	Seat displace outside aircraft (4) Helmet absorbed excessive loading (2) Body – body part flailed longitudinally (1)
Thorax – 13 Injuries	Struck against console (4) Struck against cyclic (1) Stuck against seat (1)	Restraint exceeded human & design tolerance (4) Body / body part absorbed excess load (1) Body / body part flailed excessively (1)
Cervical Spine – 10 Injuries	Struck by intruding object (6) {one person} Struck against internal object (1)	Seat displaced outside aircraft (6) Occupiable space crushed greater than 12 in. (1)

UH-1-IT&TA – Crew	3 crew severely injured	18 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Thorax – 6 Injuries	No data reported ()	No data reported ()
Head – 4 injuries	No data reported ()	No data reported ()
Upper Extremities – 2 Injuries	No data reported ()	No data reported ()

UH-1-IT&TA – Passengers	3 passengers severely injured	33 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Head – 17 injuries	Thrown from aircraft (10) {One person} Exposed to multiple injury mechanisms (1)	Seat collapsed outside aircraft (10) {One person} Helmet not provided
Thorax – 4 Injuries	Struck against internal object (2)	Seat displaced greater than 12 in. (1) Restraint system pinned properly [sic] (1)
Abdomen – 4 Injuries	Thrown from aircraft (4) {one person}	Seat collapsed outside aircraft (4) {one person}

UH-60

UH-60 T Crashes – Pilots, Crew, & Passengers

UH-60-T – Pilots	9 pilots severely injured	31 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Head – 8 Injuries	Struck by door (4) Struck against seat and other (2) Struck against seat (1)	Impact collapsed occupiable space (3) Restraint system allowed excess longitudinal motion (1) Body part injured on jagged edges (1)
Lower Extremities – 6 injuries	Exposed to aircraft fire (2) Struck against pedals (1)	Fuel tanks ignited occupiable space (2) Impact caused excessive loading (1)
General – 4 Injuries	Struck by main rotor (2) Exposed to multiple injury mechanisms (2)	Main rotor penetrated occupiable space (2) Occupiable space collapsed greater than 12 in. (2)

UH-60-T – Crew	6 crew severely injured	28 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Head – 8 Injuries	Struck by door (4) Struck against seat and other (2) Struck against seat (1)	Impact collapsed occupiable space (3) Restraint system allowed excess longitudinal motion (1) Body part injured on jagged edges (1)
Thorax – 7 injuries	Exposed to excess deceleration (3) Caught in/under/between other (2) Exposed to aircraft fire (1)	Body part flailed outside aircraft (3) Armor (1) Body part trapped/pinned (1) Fuel tanks ignited occupiable space (1)
Abdomen – 5 Injuries	Exposed to excess deceleration (2) Struck against structure (1)	Body / body part flailed outside aircraft (2) Restraint system not provided (1)

UH-60

UH-60 T Crashes – Pilots, Crew, & Passengers, *continued*

UH-60-T – Passengers	15 passengers severely injured	68 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Thorax – 31 injuries	Struck against internal objects, structure, unknown (12) Caught under ceiling (9) Exposed to multiple mech (3)	Impact displaced occupiable space (13) Restraint system not provided excess motion (5) Body / body part flailed excessively (2)
Head – 13 Injuries	Struck by ceiling, structure, internal objects (9) Exposed to multiple injury mechanisms (2) Struck by internal object (1)	Ceiling collapsed occupiable space (4) Body part flailed excessively (2)Restraint system not used ()
Abdomen – 8 Injuries	Exposed to multiple injury mechanisms (3) Struck against internal object (2) Exposed to aircraft fire	Restraint system not provided (2) Restraint system broke, excessive motion (1) Fuel tanks ignited occupiable spaces (1)

UH-60 IT&TA Crashes – Pilots, Crew, & Passengers

UH-60-IT&TA – Pilots	12 Pilots severely injured	42 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Thorax – 16 injuries	Caught in/under/between instrument panel (4) Exposed to excess deceleration (2) Exposed to aircraft fire (2)	Impact collapsed occupiable space (5) Body part absorbed excessive loading (1) Fuel tanks ruptured excessively (1)
Head – 6 injuries	Struck against ceiling (1) Struck against internal object (1) Struck cyclic (1) Caught under/in aircraft (1)	Body part flailed excessively (2) Helmet allowed excessive loading (1) Structure collapsed greater than 12 in.
Thoracic Lumbar Spine – 6 injuries	Experienced or exposed to excess deceleration (5)	Seat provided inadequate clearance (4) Impact exceeded human & design limits (1)

UH-60
UH-60 IT&TA Crashes – Pilots, Crew, & Passengers, *continued*

UH-60-IT&TA – Crew	6 crew severely injured	14 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Thorax – 6 injuries	Exposed to aircraft fire (3) Experienced penetrating object (1) Struck against internal object / window (2)	Fuel tanks ruptured excessively (3) Body part absorbed excess loading (2) Restraint system not used, excess motion (1)
Head – 4 Injuries	Struck external object (2) Caught in/under/between helmet (2)	Restraint system not used, excess motion (4)
General – 2 Injuries	Exposed to excess deceleration (2)	Impact exceeded human and design limits (2)

UH-60-IT&TA – Passengers	12 passengers severely injured	15 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
General– 8 injuries	Exposed to excess deceleration (7) Struck against structure (1)	Impact exceeded human & design limit (7)Body absorbed excessive loading (1)
Thorax – 3 Injuries	Exposed to aircraft fire (3)	Fuel tanks ruptured excessively (3)
Head – 2 Injuries	Struck against structure (2)	Body part absorbed excessive loading (2)

OH-6

OH-6-T – Pilots	0 pilots severely injured	0 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**

OH-6-T – Crew	0 Crew severely injured	0 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**

OH-6-T – Passengers	0 passengers severely injured	0 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**

OH-6-IT&TA – Pilots	0 pilots severely injured	0 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**

OH-6-IT&TA – Crew	0 Crew severely injured	0 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**

OH-6-IT&TA – Passengers	0 passengers severely injured	0 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**

OH-58AC
OH-58AC T Crashes – Pilots, Crew, & Passengers

OH-58AC – T – Pilots	3 pilots severely injured	8 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Thoracic Lumbar Spine– 4 Injuries	Exposed to/ experienced excess deceleration (4)	Aircraft collapsed vertical (1) Seat buckled improperly (1) Seat allowed excess loading (1) Aircraft collapsed vertically (1)
Lower Extremities – 2 injuries	Struck against unknown (2)	Impact caused excessive motion (1) Impact crushed other (1)
Head – 1 Injuries	Struck against structure (1)	Helmet allowed excessive loading (1)

OH-58AC – T – Crew	0 crew severely injured	0 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**

OH-58AC – T – Passengers	0 passengers severely injured	0 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**

OH-58AC

OH-58AC IT&TA – Pilots, Crew & Passengers

OH-58AC – IT&TA – Pilots	10 pilots severely injured	52 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Head – 19 Injuries	Struck by structure or intruding object (6) Exposed to multiple injury mechanisms (1) Experience excessive deceleration (1)	Impact collapsed/ crushed occupiable space (3) External object penetrated occupiable space (1) Helmet absorbed excess loading (1)
Thoracic Lumbar Spine – 8 Injuries	Exposed to excessive deceleration (4) Exposed to multiple injury mechanisms (3)	Impact exceeded human & design limits (4) Seat absorbed excessive loading (3)
Thorax – 6 injuries	Exposed to aircraft fire (1) Exposed to multiple injury mechanisms (1) Caught in restraint system (1)	Impact ignited fuel (1) Torso restraint absorbed excessive loading (1) Restraint system allowed excessive loading (1)

OH-58AC – IT&TA – Crew	1 crew severely injured	6 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Head – 2 Injuries	No data reported ( )	Do data reported ( )
Thoracic Lumbar Spine – 1 Injuries	No data reported ( )	Do data reported ( )
Cervical Spine – 1 injuries	No data reported ( )	Do data reported ( )

OH-58AC – IT&TA – Passengers	2 passenger severely injured	10 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Head – 2 Injuries	Struck against structure (1) Struck by windshield (1)	Impact collapsed occupiable space (1) Windshield broke, excessive loading (1)
Thorax – 2 Injuries	Exposed to aircraft fire (1) Struck against seat (1)	Impact ignited fuel (1) Seat displaced improperly (1)
General – 1 injuries	Exposed to aircraft fire (1)	Impact ignited fuel (1)

OH-58D
UH-58D T Crashes – Pilots, Crew, & Passengers

OH-58D – T – Pilots	2 pilots severely injured	7 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Lower Extremities – 3 Injuries	Caught under instrument panel (2) Struck against floor (1)	Instrument panel broke, occupiable space (2) Other broke occupiable space (1)
Head – 1 Injury	Struck by NVG / PNVS (1)	Night vision device unknown / unclassified, unknown / unclassified (1)
Thoracic Lumbar Spine – 1 injury	Exposed to excessive deceleration (1)	Seat bottomed out, excessive loading (1)

OH-58D – T – Crew	0 crew severely injured	0 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**

OH-58D – T – Passengers	0 passengers severely injured	0 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**

OH-58D
UH-58D IT&TA Crashes – Pilots, Crew, & Passengers

OH-58D – IT&TA – Pilots	5 pilots severely injured	15 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**
Thorax – 6 Injuries	Struck by instrument panel (1) Struck by multiple injury mechanisms (1) Exposed to excessive deceleration (1)	Structure / occupiable space crushed greater than 12 in. (3) Impact exceeded human & design limits (1) {Crashes (2) were rated partially survivable S=2}
Head – 3 Injury	Struck by multiple injury mechanisms (2) Struck by instrument panel (1)	Occupiable space / structure crushed greater than 12 in. (3)
Abdomen – 2 injury	Struck by main rotor (1) Struck by instrument panel (1)	Main rotor penetrated occupiable space (1) Structure collapsed greater than 12 in. (1)

OH-58D – IT&TA – Crew	0 crew severely injured	0 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**

OH-58D – IT&TA – Passengers	0 passengers severely injured	0 injuries
Body Region	**Injury Action (#)**	**Injury Cause (#)**

Appendix K – Injury Summary Tables

Table 1 – Injury Summary, AH-1

AH-1							
Injury Data for S=1&2 Crashes	**INJURY_INFORMATION Database Table**				**AIRCRAFT_INFORMATION Database Table**		
Injury Type	T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)		T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)
Fatal & Missing	6	2	8		2	0	2
Total & Partially Disabling Injured	1	2	3		4	2	6
Others Injured	41	24	65		3	1	4
Total Severely Injured	7	4	11		6	2	8
Total People Injured	48	28	76		9	3	12
People Not Injured					13	3	16
Crashes	29	16	45		57	22	79
Severe Inj. /crash	0.2	0.3	0.2		0.1	0.1	0.1
Total Injured / crash	1.7	1.8	1.7		0.2	0.1	0.2
Total people / crash					0.4	0.3	0.4

Table 2 – Injury Summary, AH-64

AH-64							
Injury Data for S=1&2 Crashes	**INJURY_INFORMATION Database Table**				**AIRCRAFT_INFORMATION Database Table**		
Injury Type	T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)		T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)
Fatal & Missing	2	4	6		2	4	6
Total & Partially Disabling Injured	3	2	5		24	14	38
Others Injured	26	23	49		9	8	17
Total Severely Injured	5	6	11		26	18	44
Total People Injured	31	29	60		35	26	61
People Not Injured					25	10	35
Crashes	18	17	35		32	19	51
Severe Inj. /crash	0.3	0.4	0.3		0.8	0.9	0.9
Total Injured / crash	1.7	1.7	1.7		1.1	1.4	1.2
Total people / crash					1.9	1.9	1.9

Table 3 – Injury Summary, CH-47

CH-47							
Injury Data for S=1&2 Crashes	**INJURY_INFORMATION Database Table**				**AIRCRAFT_INFORMATION Database Table**		
Injury Type	T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)		T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)
Fatal & Missing	13	1	14		3	0	3
Total & Partially Disabling Injured	0	0	0		12	0	12
Others Injured	48	4	52		21	0	21
Total Severely Injured	13	1	14		15	0	15
Total People Injured	61	5	66		36	0	36
People Not Injured					67	0	67
Crashes	14	2	16		17	2	19
Severe Inj. /crash	0.9	0.5	0.9		0.9	0.0	0.8
Total Injured / crash	4.4	2.5	4.1		2.1	0.0	1.9
Total people / crash					6.1	0.0	5.4

Table 4 – Injury Summary, OH-6

OH-6							
Injury Data for S=1&2 Crashes	**INJURY_INFORMATION Database Table**				**AIRCRAFT_INFORMATION Database Table**		
Injury Type	T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)		T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)
Fatal & Missing	0	0	0		0	0	0
Total & Partially Disabling Injured	0	0	0		1	0	1
Others Injured	27	1	28		1	0	1
Total Severely Injured	0	0	0		1	0	1
Total People Injured	27	1	28		2	0	2
People Not Injured					3	0	3
Crashes	15	1	16		28	1	29
Severe Inj. /crash	0.0	0.0	0.0		0.0	0.0	0.0
Total Injured / crash	1.8	1.0	1.8		0.1	0.0	0.1
Total people / crash					0.2	0.0	0.2

Table 5 – Injury Summary, OH-58AC

OH-58AC							
Injury Data for S=1&2 Crashes	**INJURY_INFORMATION Database Table**				**AIRCRAFT_INFORMATION Database Table**		
Injury Type	T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)		T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)
Fatal & Missing	1	9	10		0	3	3
Total & Partially Disabling Injured	2	4	6		18	7	25
Others Injured	75	35	110		14	4	18
Total Severely Injured	3	13	16		18	10	28
Total People Injured	78	48	126		32	14	46
People Not Injured					30	2	32
Crashes	50	24	74		69	30	99
Severe Inj. /crash	0.1	0.5	0.2		0.3	0.3	0.3
Total Injured / crash	1.6	2.0	1.7		0.5	0.5	0.5
Total people / crash					0.9	0.5	0.8

Table 6 – Injury Summary, OH-58D

OH-58D							
Injury Data for S=1&2 Crashes	**INJURY_INFORMATION Database Table**				**AIRCRAFT_INFORMATION Database Table**		
Injury Type	T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)		T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)
Fatal & Missing	0	4	4		0	2	2
Total & Partially Disabling Injured	2	1	3		17	9	26
Others Injured	25	13	38		13	5	18
Total Severely Injured	2	5	7		17	11	28
Total People Injured	27	18	45		30	16	46
People Not Injured					22	4	26
Crashes	15	8	23		27	10	37
Severe Inj. /crash	0.1	0.6	0.3		0.6	1.1	0.8
Total Injured / crash	1.8	2.3	2.0		1.1	1.6	1.2
Total people / crash					1.9	2.0	1.9

Table 7 – Injury Summary, UH-1

UH-1							
Injury Data for S=1&2 Crashes	**INJURY_INFORMATION Database Table**				**AIRCRAFT_INFORMATION Database Table**		
Injury Type	T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)		T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)
Fatal & Missing	6	17	23		1	0	1
Total & Partially Disabling Injured	6	4	10		38	18	56
Others Injured	140	154	294		16	4	20
Total Severely Injured	12	21	33		39	18	57
Total People Injured	152	175	327		55	22	77
People Not Injured					51	2	53
Crashes	56	37	93		84	47	131
Severe Inj. /crash	0.2	0.6	0.4		0.5	0.4	0.4
Total Injured / crash	2.7	4.7	3.5		0.7	0.5	0.6
Total people / crash					1.3	0.5	1.0

Table 8 – Injury Summary, UH-60

UH-64							
Injury Data for S=1&2 Crashes	**INJURY_INFORMATION Database Table**				**AIRCRAFT_INFORMATION Database Table**		
Injury Type	T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)		T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)
Fatal & Missing	21	24	45		15	20	35
Total & Partially Disabling Injured	9	6	15		37	16	53
Others Injured	47	23	70		11	3	14
Total Severely Injured	30	30	60		52	36	88
Total People Injured	77	53	130		63	39	102
People Not Injured			0		51	10	61
Crashes	17	11	28		25	14	39
Severe Inj. /crash	1.8	2.7	2.1		2.1	2.6	2.3
Total Injured / crash	4.5	4.8	4.6		2.5	2.8	2.6
Total people / crash					4.6	3.5	4.2

Table 9 – Injury Summary, All Aircraft Combined

ALL AIRCRAFT COMBINED							
Injury Data for S=1&2 Crashes	**INJURY_INFORMATION Database Table**				**AIRCRAFT_INFORMATION Database Table**		
Injury Type	T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)		T Crashes (no.)	IT&TA Crashes (no.)	Sum (no.)
Fatal & Missing	49	61	110		23	29	52
Total & Partially Disabling Injured	23	19	42		151	66	217
Others Injured	429	277	706		88	25	113
Total Severely Injured	72	80	152		174	95	269
Total People Injured	501	357	858		262	120	382
People Not Injured	0	0	0		262	31	293
Crashes	214	116	330		339	145	484
Severe Inj. /crash	0.3	0.7	0.5		0.5	0.7	0.6
Total Injured / crash	2.3	3.1	2.6		0.8	0.8	0.8
Total people / crash					1.5	1.0	1.4

Appendix L – Inflight Cumulative Impact Velocity

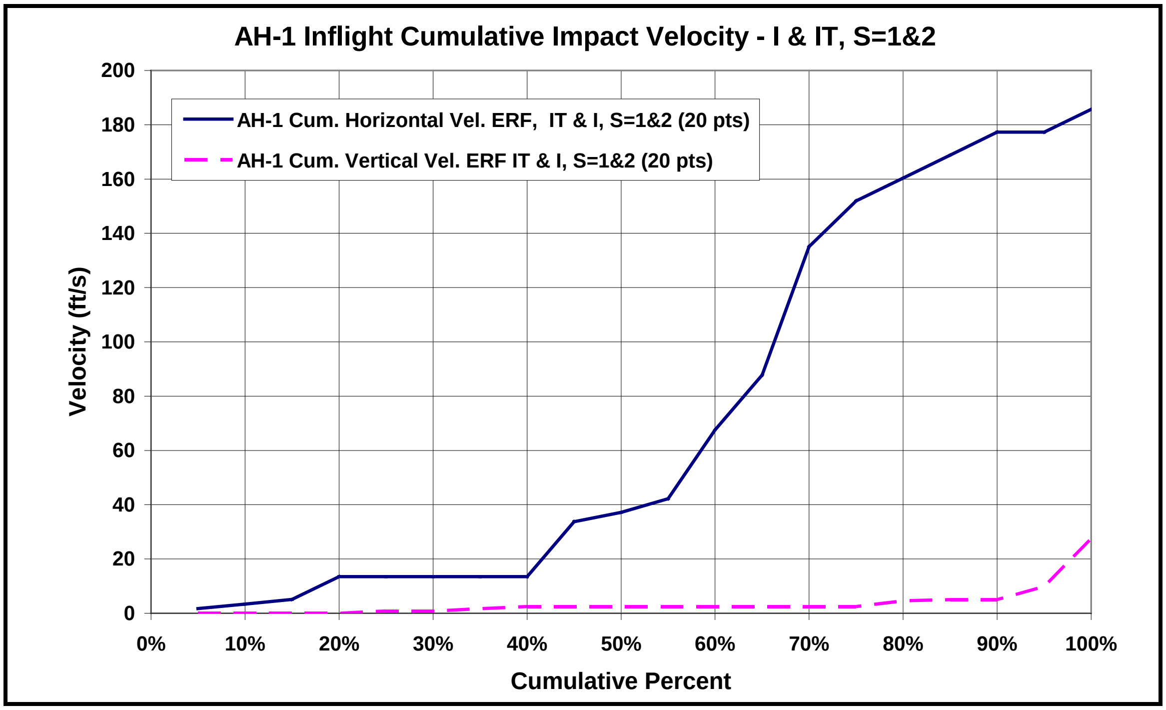

Figure L-1 – Inflight Cumulative Impact Velocity, AH-1

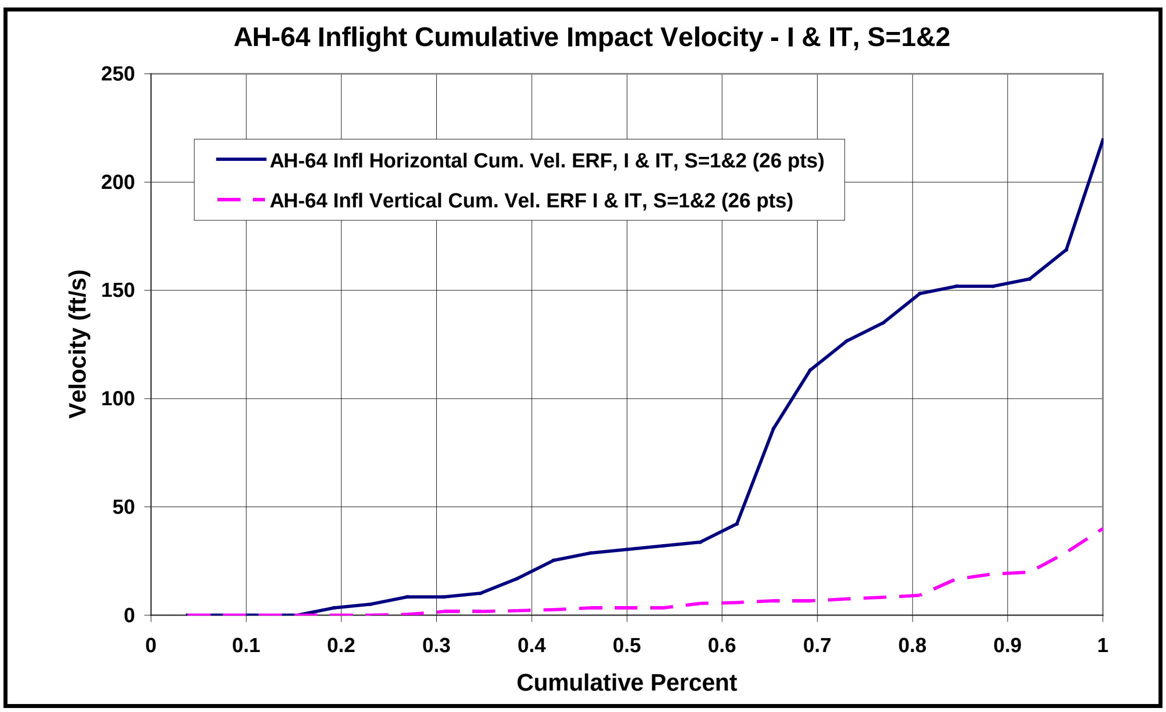

Figure L-2 – Inflight Cumulative Impact Velocity, AH-64

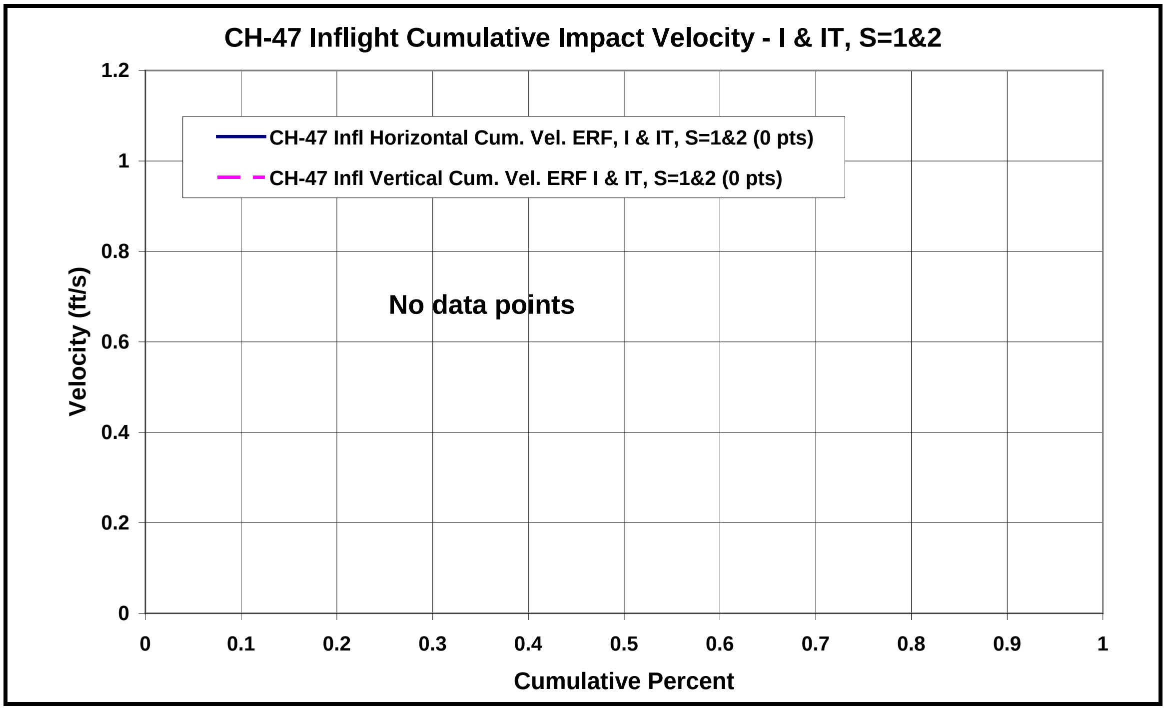

Figure L-3 – Inflight Cumulative Impact Velocity, CH-47

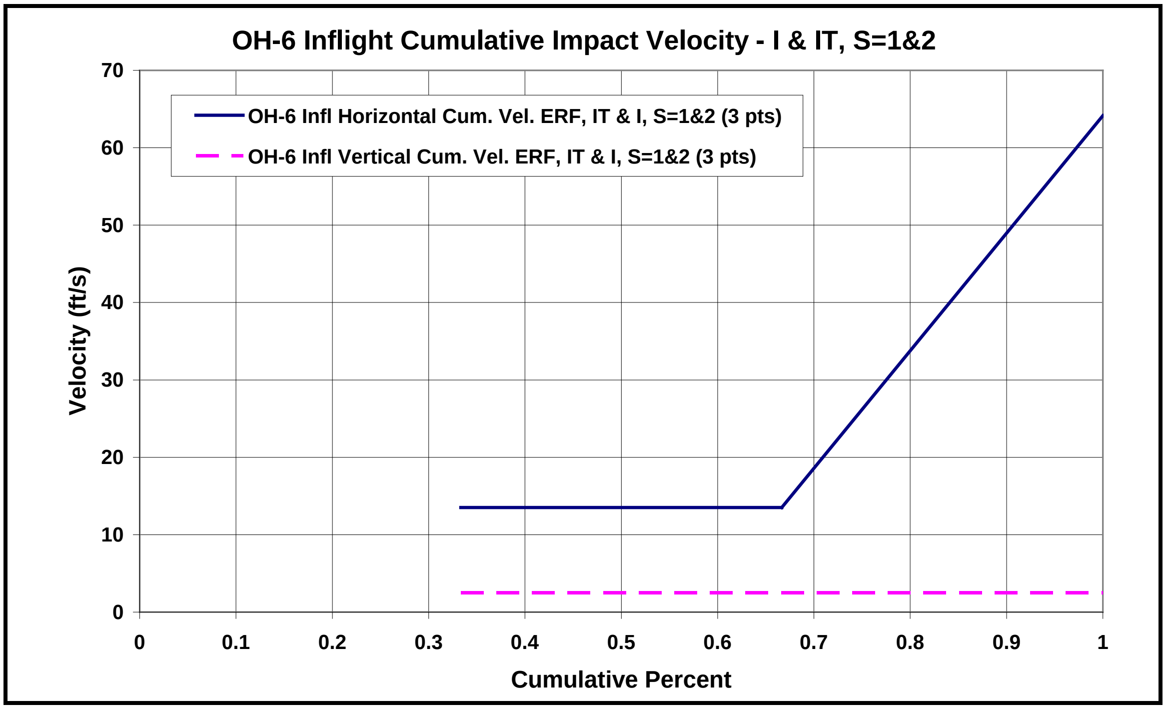

Figure L-4 – Inflight Cumulative Impact Velocity, OH-6

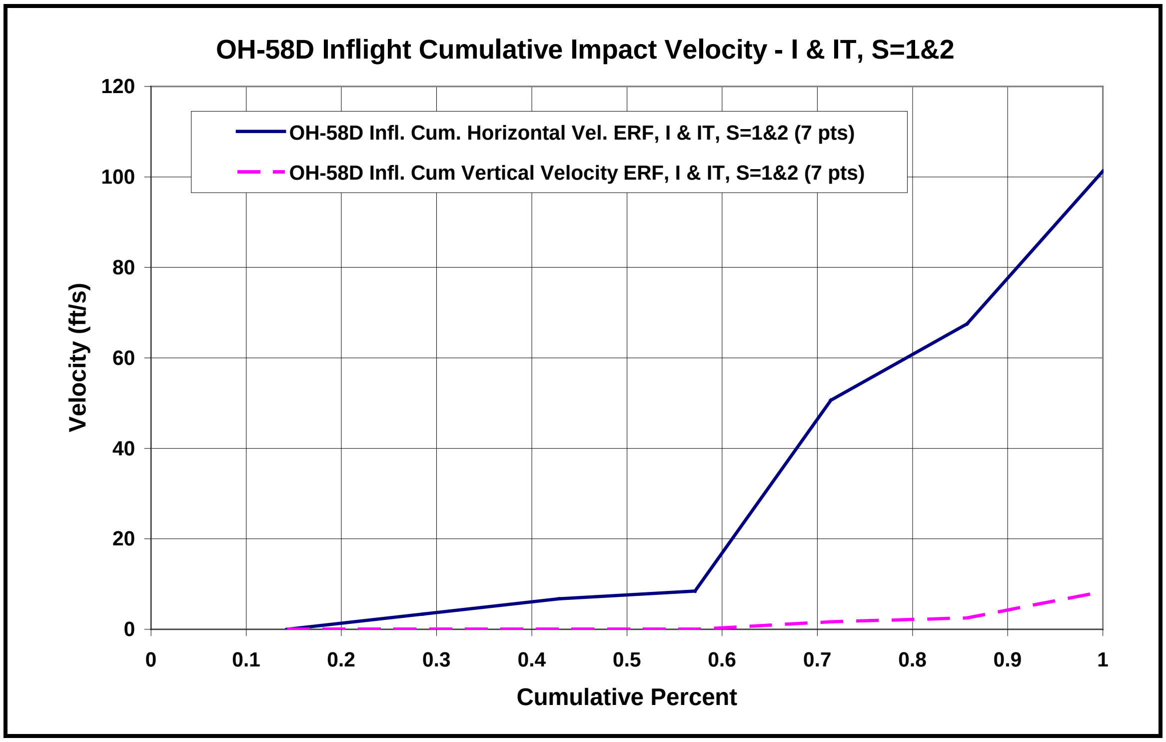

Figure L-5 – Inflight Cumulative Impact Velocity, 58D

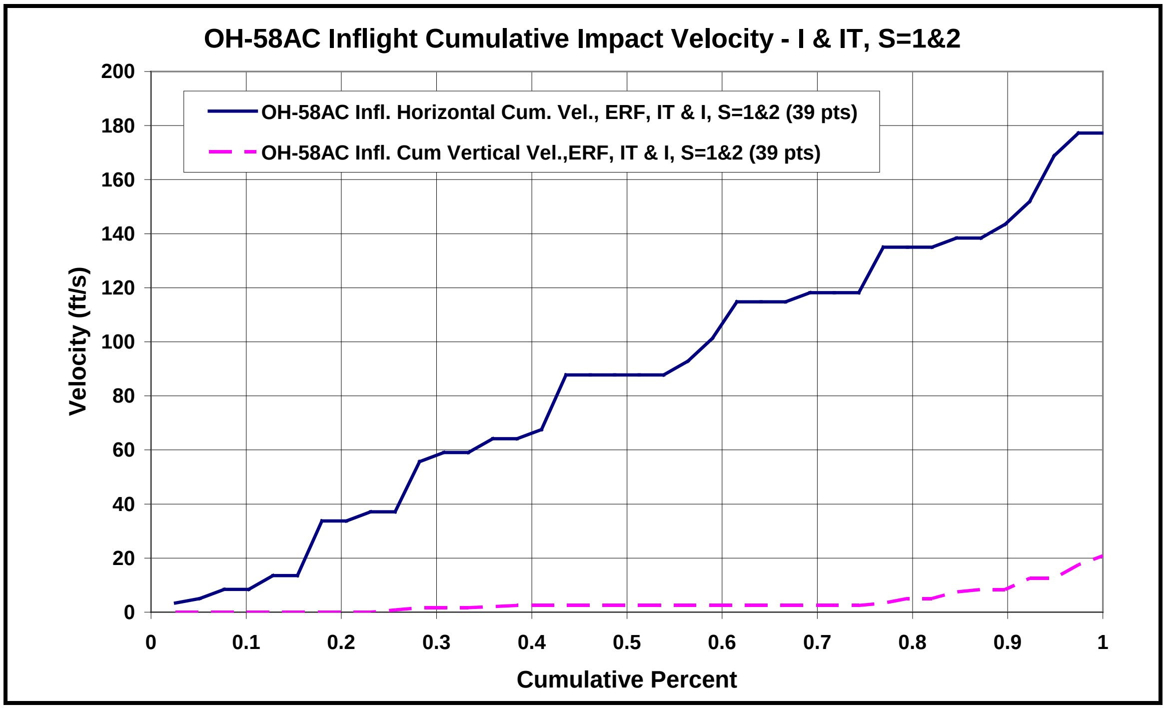

Figure L-6 – Inflight Cumulative Impact Velocity, OH-58AC

Distribution: Unlimited

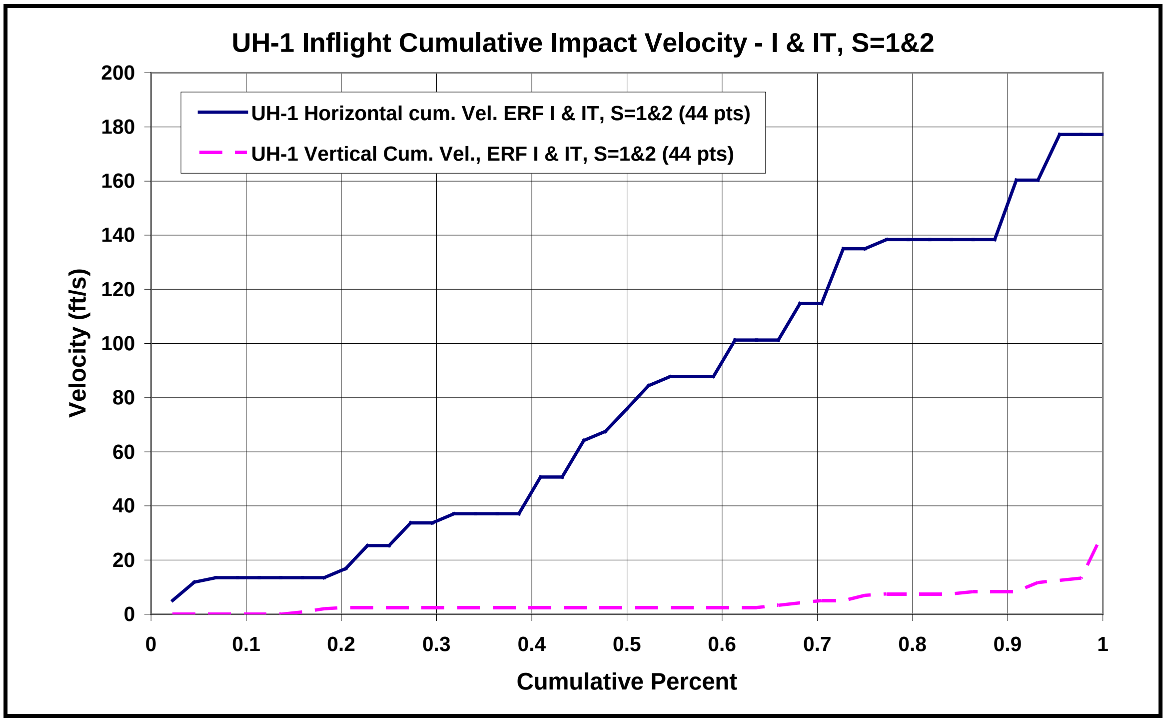

Figure L-7 – Inflight Cumulative Impact Velocity, UH-1

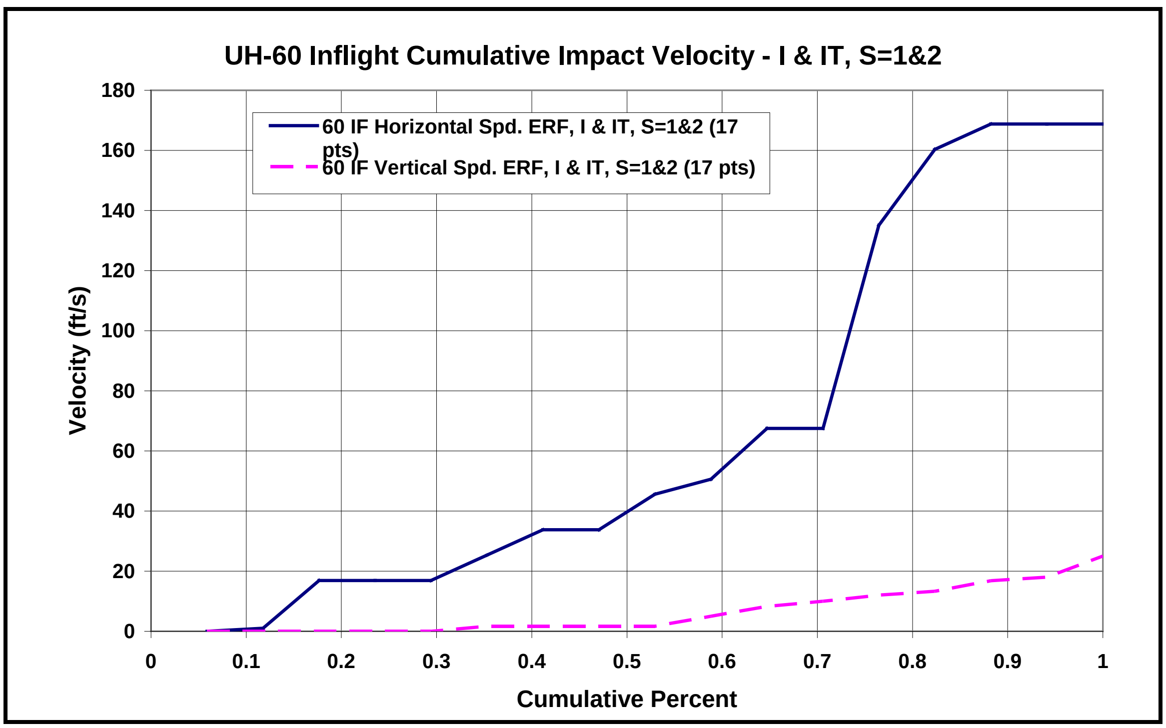

Figure L-8 – Inflight Cumulative Impact Velocity, UH-60

Appendix M – Protective Equipment Summary

Table M-1 –AH-1 Protective Equipment Summary (T and IT&TA)

AH-1 T	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	28	28	28	28	0	28	0	20	10	4	28	0	0	1	15	3
Shoulder Harness	28	28	28	28	0	28	0	20	2	4	18	0	0	2	14	3
Inertia Reel	28	28	28	28	0	27	1	18	8	4	23	0	0	3	13	3
Seat/Litter	28	28	28	28	0	28	0	18	5	9	12	0	0	6	8	3
AH-1 IT &TA																
Lapbelt	22	22	22	22	0	22	0	20	7	6	23	0	0	0	6	3
Shoulder Harness	22	22	22	22	0	22	2	16	3	8	21	0	0	1	8	3
Inertia Reel	22	22	22	22	0	20	0	20	6	5	16	0	0	0	6	3
Seat/Litter	22	22	22	22	0	22	0	16	8	7	8	0	0	1	4	3

Table M-2 – AH-64 Protective Equipment Summary (T and IT&TA)

AH-64 T	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	36	34	36	36	0	30	0	23	7	5	23	1	10	0	12	0
Shoulder Harness	39	37	39	39	0	35	0	24	11	10	23	3	11	3	12	0
Inertia Reel	36	34	36	36	0	32	0	21	11	7	23	2	8	0	12	0
Seat/Litter	35	35	35	35	0	33	0	19	12	11	20	4	7	2	11	1
AH-64 IT &TA																
Lapbelt	28	28	28	27	1	24	2	10	14	14	10	8	2	8	10	6
Shoulder Harness	28	28	28	28	0	28	0	11	15	14	10	6	2	8	8	4
Inertia Reel	20	20	20	20	0	19	1	15	3	3	15	1	1	2	8	4
Seat/Litter	22	22	22	22	0	21	0	12	8	8	10	2	0	2	9	4

Table M-3 – CH-47 Protective Equipment Summary (T and IT&TA Pilots)

CH-47 T Pilots	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	10	10	10	10	0	10	0	8	2	6	4	0	4	2	8	1
Shoulder Harness	10	10	10	10	0	10	0	8	2	6	4	0	4	2	8	1
Inertia Reel	10	10	10	10	0	10	0	9	1	5	5	0	4	1	9	1
Seat/Litter	8	8	8	8	0	8	0	6	2	1	7	0	2	1	7	1
CH-47 IT &TA Pilots																
Lapbelt	4	4	4	4	0	3	0	2	1	0	3	0	0	0	0	1
Shoulder Harness	4	4	4	4	0	3	0	2	1	0	3	0	0	0	0	1
Inertia Reel	3	3	3	3	0	3	0	2	0	0	2	0	0	0	0	0
Seat/Litter	4	4	4	4	0	2	0	2	1	0	3	0	0	0	0	1

Table M-4 – CH-47 Protective Equipment Summary (T and IT&TA Crew, T and IT&TA Pax)

CH-47 T Crew	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	11	8	8	3	8	3	0	3	2	0	5	0	2	0	5	2
Shoulder Harness	6	0	0	0	6	0	0	0	0	0	0	0	0	0	0	2
Inertia Reel	6	0	0	0	6	0	0	0	0	0	0	0	0	0	0	2
Seat/Litter	12	12	9	6	6	6	0	6	0	0	6	0	0	0	6	2
CH-47 IT &TA Crew																
Lapbelt	2	2	2	1	1	1	0	1	0	0	1	0	0	0	0	0
Shoulder Harness	2	2	2	0	2	0	0	0	0	0	0	0	0	0	0	0
Inertia Reel	2	1	2	0	2	0	0	0	0	0	0	0	0	0	0	0
Seat/Litter	2	2	2	1	1	1	0	1	0	0	1	0	0	0	0	0

CH-47 T Pax	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	3	3	3	2	1	2	0	1	1	1	1	1	1	0	2	0
Shoulder Harness	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Inertia Reel	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Seat/Litter	3	3	3	3	0	3	0	0	3	0	3	0	3	0	3	0
CH-47 IT &TA Pax																
Lapbelt	13	13	13	12	1	12	0	11	1	1	11	0	0	0	0	0
Shoulder Harness	0															
Inertia Reel	0															
Seat/Litter	13	13	13	13	0	13	0	12	1	1	12	0	0	0	0	0

Table M-5 –OH-6 Protective Equipment Summary (T and IT&TA Pilots)

OH-6 T Pilots	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	5	5	5	5	0	5	0	3	2	2	3	0	0	0	4	0
Shoulder Harness	5	5	5	5	0	5	0	3	2	2	3	0	0	0	4	0
Inertia Reel	5	5	5	5	0	5	0	2	2	2	3	0	0	0	4	0
Seat/Litter	5	5	5	5	0	5	0	0	4	2	3	0	0	2	2	0
OH-6 IT &TA Pilots																
Lapbelt	0															
Shoulder Harness	0															
Inertia Reel	0															
Seat/Litter	0															

Table M-6 – OH-6 Protective Equipment Summary (T and IT&TA Crew, T and IT&TA Pax)

OH-6 T Crew	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	0															
Shoulder Harness	0															
Inertia Reel	0															
Seat/Litter	0															
OH-6 IT &TA Crew																
Lapbelt	0															
Shoulder Harness	0															
Inertia Reel	0															
Seat/Litter	0															

OH-6 T Pax	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	0															
Shoulder Harness	0															
Inertia Reel	0															
Seat/Litter	0															
OH-6 IT &TA Pax																
Lapbelt	0															
Shoulder Harness	0															
Inertia Reel	0															
Seat/Litter	0															

Table M-7 – OH-58AC Protective Equipment Summary (T and IT&TA Pilots)

OH-58AC T Pilots	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	63	63	63	63	0	58	0	47	10	17	40	0	6	1	28	2
Shoulder Harness	64	64	64	64	0	63	0	51	13	19	44	1	6	0	30	3
Inertia Reel	62	61	61	60	2	59	0	47	12	12	47	0	6	0	29	2
Seat/Litter	63	63	63	63	0	56	3	34	21	18	40	2	6	5	25	3
OH-58AC IT &TA Pilots																
Lapbelt	25	25	25	25	0	25	0	14	8	6	18	1	1	2	3	0
Shoulder Harness	25	25	25	25	0	25	0	14	8	6	18	1	1	2	3	0
Inertia Reel	25	25	25	25	0	25	0	13	9	6	18	0	2	2	3	0
Seat/Litter	25	25	25	25	0	22	0	12	9	6	16	2	0	1	4	0

Table M-8 – OH-58AC Protective Equipment Summary (T and IT&TA Crew, T and IT&TA Pax)

OH-58AC T Crew	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	15	15	15	15	0	15	0	10	5	4	11	1	0	0	6	0
Shoulder Harness	14	14	14	14	0	14	0	9	5	6	8	0	0	0	5	0
Inertia Reel	14	12	12	12	2	12	1	9	4	3	10	0	0	0	5	0
Seat/Litter	14	14	14	14	0	13	0	6	6	6	7	0	1	2	4	0
OH-58AC IT &TA Crew																
Lapbelt	3	3	3	3	0	3	0	3	0	0	3	0	0	0	0	0
Shoulder Harness	3	3	3	3	0	3	0	3	0	0	3	0	0	0	0	0
Inertia Reel	3	3	3	3	0	3	0	2	1	1	2	0	0	0	0	0
Seat/Litter	3	3	3	3	0	3	0	3	0	0	3	0	0	0	0	0

OH-58AC T Pax	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	8	8	8	8	0	7	0	6	1	0	7	0	1	0	2	0
Shoulder Harness	8	7	7	7	1	7	0	6	1	0	7	0	1	0	1	0
Inertia Reel	7	3	2	3	4	3	0	2	1	0	3	0	0	0	0	0
Seat/Litter	8	8	8	8	0	8	0	7	0	0	8	0	1	0	2	0
OH-58AC IT &TA Pax																
Lapbelt	8	8	8	8	0	7	1	6	2	2	6	1	0	0	0	0
Shoulder Harness	7	7	7	7	0	6	1	5	2	3	4	0	0	0	0	0
Inertia Reel	7	5	5	5	2	5	0	5	0	2	3	0	0	0	0	0
Seat/Litter	8	8	8	8	0	8	0	4	3	3	4	1	0	0	0	0

Table M-9 – OH-58D Protective Equipment Summary (T and IT&TA Pilots)

OH-58D T Pilots	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	28	28	28	28	0	27	0	18	6	8	18	4	5	1	13	0
Shoulder Harness	26	26	26	26	0	26	0	17	6	8	17	4	4	2	11	0
Inertia Reel	25	25	25	25	0	24	1	18	2	6	18	3	4	1	11	0
Seat/Litter	24	24	24	24	0	24	0	12	9	9	14	6	4	1	13	0
OH-58D IT &TA Pilots																
Lapbelt	8	8	8	8	0	6	2	5	3	3	5	0	4	2	4	1
Shoulder Harness	13	13	13	13	0	9	4	6	7	6	5	4	3	2	7	2
Inertia Reel	6	6	6	6	0	5	1	4	2	2	2	0	0	0	2	1
Seat/Litter	7	7	7	7	0	7	0	3	4	3	4	2	0	1	4	3

Table M-10 – OH-58D Protective Equipment Summary (T and IT&TA Crew, T and IT&TA Pax)

OH-58D T Crew	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	5	5	5	5	0	5	0	4	1	2	3	1	1	1	3	0
Shoulder Harness	5	5	5	5	0	5	0	4	1	2	3	1	1	1	3	0
Inertia Reel	4	4	4	4	0	4	0	4	0	1	3	0	1	0	3	0
Seat/Litter	5	5	5	5	0	5	0	2	3	2	2	2	0	1	2	0
OH-58D IT &TA Crew																
Lapbelt	0															
Shoulder Harness	0															
Inertia Reel	0															
Seat/Litter	0															

OH-58D T Pax	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	1	1	1	1	0	1	0	1	0	0	1	0	0	0	1	0
Shoulder Harness	1	1	1	1	0	1	0	1	0	0	1	0	0	0	1	0
Inertia Reel	1	1	1	1	0	1	0	1	0	0	1	0	0	0	1	0
Seat/Litter	1	1	1	1	0	1	0	1	0	0	1	0	0	0	1	0
OH-58D IT &TA Pax																
Lapbelt	0															
Shoulder Harness	0															
Inertia Reel	0															
Seat/Litter	0															

Table M-11 – UH-1 Protective Equipment Summary (T and IT&TA Pilots)

UH-1 T Pilots	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	82	82	82	82	0	78	0	65	10	12	65	0	3	0	21	3
Shoulder Harness	79	77	77	77	2	75	0	64	7	13	60	0	2	0	20	3
Inertia Reel	78	76	76	74	4	72	0	59	8	12	60	0	2	0	20	3
Seat/Litter	79	79	79	79	0	77	0	53	19	19	55	1	2	6	13	3
UH-1 IT &TA Pilots																
Lapbelt	47	46	46	46	0	44	2	29	17	12	34	1	1	1	5	6
Shoulder Harness	46	43	43	43	2	43	0	28	15	11	32	1	1	2	3	6
Inertia Reel	44	41	41	40	3	41	0	30	11	5	36	0	0	0	4	6
Seat/Litter	47	45	45	45	0	41	2	24	21	13	30	0	2	1	3	6

Distribution: Unlimited

Table M-12 – UH-1 Protective Equipment Summary (T and IT&TA Crew, T and IT&TA Pax)

UH-1 T Crew	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	31	31	30	26	4	27	0	20	6	6	21	1	0	1	7	3
Shoulder Harness	19	5	6	5	13	5	0	4	0	0	5	0	0	0	1	2
Inertia Reel	0	4	5	4	12	5	0	4	1	0	5	0	0	0	0	2
Seat/Litter	0	30	30	29	1	28	1	17	11	9	20	0	1	2	7	3
UH-1 IT &TA Crew																
Lapbelt	31	31	31	30	1	27	3	19	10	9	21	0	1	1	2	0
Shoulder Harness	23	1	1	1	22	1	0	1	0	0	1	0	0	0	0	0
Inertia Reel	23	1	1	1	22	1	0	1	0	0	1	0	0	0	0	0
Seat/Litter	31	31	31	30	1	29	0	16	13	2	27	0	0	0	3	0

UH-1 T Pax	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	60	60	60	56	4	48	0	28	20	14	34	3	0	2	17	2
Shoulder Harness	45	1	1	1	36	1	0	1	0	1	0	0	0	0	0	2
Inertia Reel	45	1	1	1	36	1	0	1	0	1	0	0	0	0	0	2
Seat/Litter	60	60	60	60	0	52	2	23	22	14	36	0	0	5	14	2
UH-1 IT &TA Pax																
Lapbelt	49	48	48	45	2	43	4	20	27	14	32	0	0	0	0	4
Shoulder Harness	34	2	2	2	31	2	0	1	1	1	1	0	0	0	0	3
Inertia Reel	34	1	1	1	32	1	0	1	0	0	1	0	0	0	0	3
Seat/Litter	50	50	50	50	0	42	1	16	26	6	36	0	0	0	0	4

Table M-13 – UH-60 Protective Equipment Summary (T and IT&TA Pilots)

UH-60 T Pilots	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	35	35	35	35	0	34	0	23	7	7	0	0	6	1	13	5
Shoulder Harness	35	35	35	35	0	32	2	19	11	9	0	1	5	4	10	5
Inertia Reel	38	38	38	38	0	35	2	18	14	8	0	5	4	1	16	7
Seat/Litter	35	35	35	35	0	28	5	16	14	13	0	2	4	4	10	5
UH-60 IT &TA Pilots																
Lapbelt	13	13	13	13	0	13	0	7	4	4	0	1	0	0	5	4
Shoulder Harness	15	15	15	15	0	14	1	4	9	8	0	2	1	3	4	5
Inertia Reel	13	13	13	13	0	10	1	5	5	3	0	1	0	0	5	4
Seat/Litter	16	16	16	16	0	9	5	5	7	3	0	3	1	0	8	4

Table M-14 – UH-60 Protective Equipment Summary (T and IT&TA Crew, T and IT&TA Pax)

UH-60 T Crew	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	15	13	13	11	4	11	0	7	3	1	9	0	2	0	6	3
Shoulder Harness	15	12	11	9	6	10	0	5	4	2	7	0	2	1	4	3
Inertia Reel	13	13	13	11	2	11	0	6	4	2	9	1	2	0	7	2
Seat/Litter	20	19	19	19	1	11	8	7	11	7	11	4	3	2	10	3
UH-60 IT &TA Crew																
Lapbelt	6	6	6	2	4	1	1	0	1	0	1	0	0	0	0	1
Shoulder Harness	6	6	6	1	5	1	0	0	0	0	0	0	0	0	0	1
Inertia Reel	6	5	5	2	4	2	0	0	1	0	1	0	0	0	0	1
Seat/Litter	9	9	8	8	1	4	3	2	5	4	3	3	0	1	3	1

UH-60 T Pax	# Reported	Device Available (# Yes)	Device Required (# Yes)	Device Used (# Yes)	Device Used (# No)	Device Functioned (# Yes)	Device Functioned (# No)	Device Prevented Injuries (# Yes)	Device Prevented Injuries (# No)	Device Reduced Injuries (# Yes)	Device Reduced Injuries (# No)	Device Allowed Injuries (# Yes)	Device Allowed Injuries (# No)	Device Produced Injuries (# Yes)	Device Produced Injuries (# No)	Severe Injuries (#)
Lapbelt	27	26	26	19	5	18	2	11	7	8	10	1	1	2	8	9
Shoulder Harness	25	22	20	7	14	6	1	3	3	3	3	0	1	2	3	8
Inertia Reel	13	4	3	3	10	2	1	2	0	1	1	0	0	0	0	4
Seat/Litter	26	25	25	21	4	16	5	7	13	13	7	0	0	8	0	8
UH-60 IT &TA Pax																
Lapbelt	5	5	5	4	1	4	0	3	1	1	0	0	0	1	3	0
Shoulder Harness	5	5	5	4	1	4	0	3	1	1	0	0	0	1	3	0
Inertia Reel	3	1	1	1	2	1	0	1	0	0	0	0	0	0	1	0
Seat/Litter	10	10	10	10	0	9	1	5	5	2	0	5	0	0	10	2